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ABSTRACT

The purpose of this guide is to explain how to use computers to promote the development of effective learning and thinking skills. The emphasis in this discussion of computer assisted instruction is on the social side of learning rather than the technical aspects of using computers. Chapter titles are: (1) "A Strategies Approach to Effective Learning and Thinking"; (2) "The Role of the Teacher in a Computer Strategies Approach"; (3) "Strategies for Teaching Thinking Skills with Computers"; (4) "Strategies for Teaching Social Skills in the Computer Environment"; (5) "LOGO and the Development of Thinking Skills"; (6) "Adventure Games and Thinking Skills"; (7) "Word Processing and Thinking Skills"; (8) "Computer Communications and the Development of Thinking Skills"; (9) "Databases and Effective Thinking"; and (10) "Spreadsheets as Tools for Thinking." Citations for additional readings from "The Computing Teacher" are also provided. (87 references) (DB)

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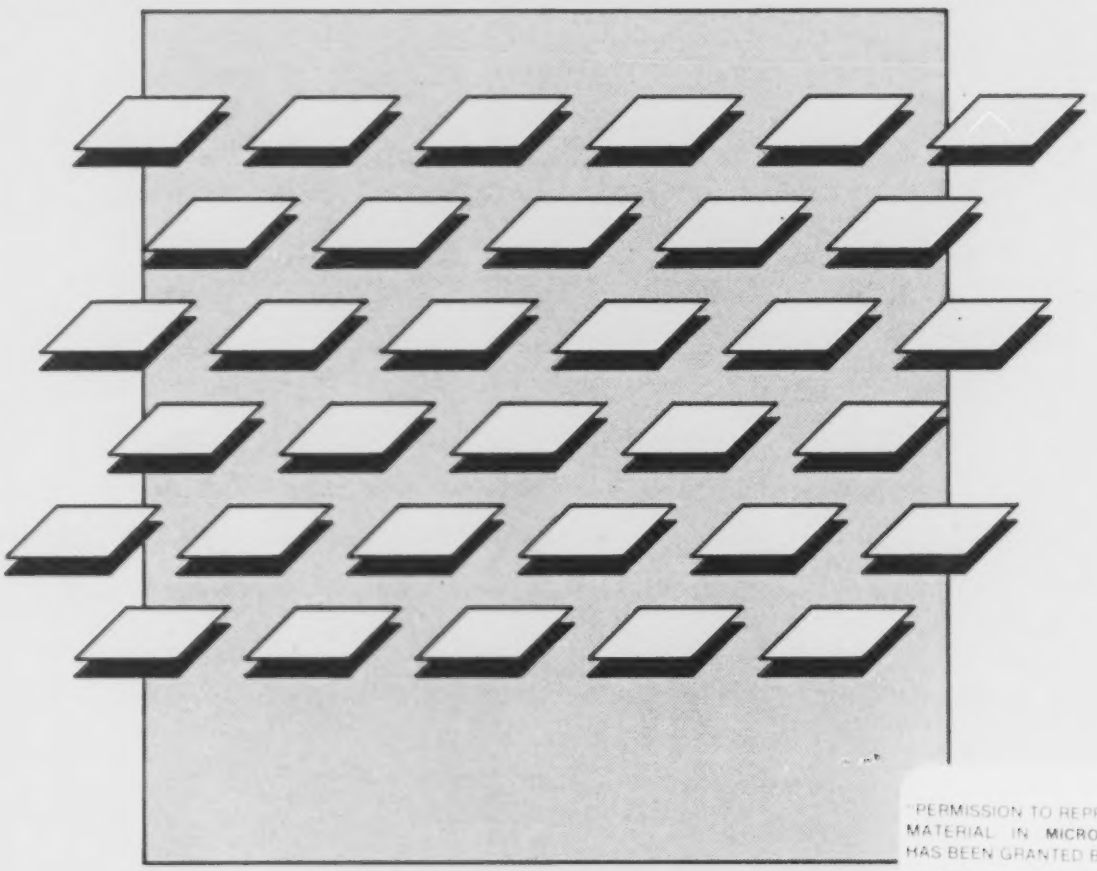

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PREFACE

The idea for writing this book came from the need to provide our students with information on computers and the learning process. Most textbooks tend to deal with the technical aspects of using computers in education and have little to say about teaching and learning. Our aim was to bridge the gap between theory and practice by explaining how to use computers to promote the development of effective learning and thinking skills.

Our own interests lend a particular bias to the kind of information presented in this book. First, we see the social side of learning as being of special importance. Second, we believe that much more attention should be given to the explicit teaching of thinking skills and strategies for problem solving. In our view, the ultimate aim of schooling is for students to become *teacher-independent thinkers*. Thus, in writing this book we have attempted to explain how computers can be used to create the best and most effective learning environments.

This book is not a technical manual on how to use computers in education. There are many books now available that explain how to use various computer applications in the classroom. Instead, our intention was to concentrate on the educational agenda—providing guidelines on how to use computers to enhance teaching and learning.

It is our hope that this work will make a positive contribution to education in the computer era.

Ken Ryba and Bill Anderson
Palmerston North, New Zealand
January, 1989

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Chapter 1 A STRATEGIES APPROACH TO EFFECTIVE THINKING AND LEARNING

Our intention in writing this book is to explain how children can use computers to help them become effective thinkers and learners. The interaction between children, computers, teachers, and their surrounding environment is important for learning. We place a great deal of importance on arranging computer environments for learning. As Papert (1987) has pointed out, the computer is but one element of a *computer learning culture*. The focus must be upon the people and how they use the computer. Teaching in this context means providing the kinds of environments where children can use the computer as a tool to enhance their intellectual self-management skills.

This book represents an effort to translate psychological and educational theory and research into practical and easy-to-implement educational intervention programs. The main goal is to capitalize on the use of computers in order to teach children to become active and purposeful thinkers, learners, and problem solvers. It is essential, however, that the teaching of thinking and learning strategies takes place within the context of a learning environment and not in isolation from the real world. This requires that teachers guide students to reflect on their thinking within different areas of the school program and their lives. This is essential to ensure that students can transfer their thinking skills from one situation to another.

In adopting a strategies approach, we recommend that students be given as much control as possible over their own behavior and learning. This requires that teachers provide students with methods that will help them to become effective thinkers and learners. In a strategies approach, the teacher directly teaches the *social skills* and the *thinking skills* that students require if they are to be good at learning. In the chapters that follow, we illustrate approaches that teachers can use with computers to develop these skills across all subject areas.

The development of thinking skills is not only important for academic development, but also for growth in the social and emotional adjustment of students. In our own work with mentally retarded students, we have illustrated the psychological benefits that can come from using computers as teaching tools (Ryba & Chapman, 1983). Strategic thinking can help students to organize their ideas and work systematically. It allows them to gain a more accurate perception of themselves by describing their ideas and feelings, explaining their point of view, and supporting what they have done (Narrol & Giblon, 1984).

DeBono (1980) has pointed out that children need a chance to develop their thinking because undeveloped thinking can lead to an inability to control emotions. He suggests that children need to be explicitly taught skills of thinking, and that appropriate social skills training can result in improved classroom behavior. DeBono contends that a skills training approach is likely to be more effective than a direct approach to dealing with misbehavior. One need only observe children interacting together with computers to see the potential that such technology has for improving learning strategies and personal adjustment.

The ultimate aim of teaching self-management skills is for learners to become independent thinkers and problem solvers.

VIEWS OF THE LEARNING PROCESS

It is common to distinguish between two major perspectives on the learning process—the *behavioral* perspective and the *cognitive* perspective.

- The **Behavioral Perspective** emphasizes the role of the environment in learning and instruction. The main aim is to understand how certain conditions in the learner's environment affect the quality and quantity of learning. The focus is on directly observing conditions outside of (external to) the individual.

- The **Cognitive Perspective** emphasizes events and processes that take place within the individual. This involves the study of a number of mental processes involved in receiving, storing, processing, retrieving, and applying information. The *active role* of the learner, rather than the environment, is considered to be the main determinant of learning.

In this book, we draw upon both perspectives to explain how learning occurs. From a behavioral perspective, we study elements of the computer learning environment and how these can be arranged to maximize learning. From a cognitive perspective, we study teaching methods that can help to promote the development of internally organized skills/processes that are required for effective thinking and learning. An important

contribution of computers has been to provide a *window* for studying some aspects of problem solving and the learning process that were not previously visible.

WHAT ARE THINKING SKILLS AND LEARNING STRATEGIES?

Thinking is a process that involves the collection, manipulation, and use of information to solve problems (Alley & Deshler, 1979). As such, it is a complex process and there is a lot of variation among authors as to what constitutes thinking skills. For the purposes of this book, we have identified a set of skills that are directly observable and which have been defined by various researchers as relating to important internal mediating processes. This set includes those skills commonly defined in the school curriculum that are known to be important for effective thinking and learning.

Thinking Skills

A. **Exploration**
observing
describing
predicting and explaining
comparing and contrasting

B. **Analysis and Planning**
identifying the problem analyzing the problem developing options for solving the problem decision making

C. **Questioning**
knowing how and when to ask questions asking different kinds of questions

D. **Self-Monitoring**
checking and regulating activities
evaluating and revising activities

Table 1

The above skills form the basis for development of cognitive (learning) strategies. These are internally organized skills or control processes by which the learner regulates his/her cognitive behavior (Gagne, 1977; Gagne & Briggs, 1974). For example, a learner can regulate his performance by asking appropriate questions and engaging in suitable checking activities.

A distinction can also be made between *intellectual skills* and *cognitive strategies* (Gagne, 1977). Intellectual skills refer to fundamental information processing activities: for example, attention, comprehension, retention, and retrieval of information. In contrast, cognitive strategies refer to the internal control processes that a learner uses to activate and regulate the intellectual activities (predicting, self-monitoring).

Your collection of cognitive strategies is like a set of tools that helps you to more effectively and efficiently acquire, retain, and apply new information. For example:

> Imagine that you assign your grade 4 or 7 class a list of words to learn for later recall. One of your more brilliant students, Cory, determined that rearranging the words under categories (strategy of categorization) would make it easier to learn the list. Obviously to be able to categorize, Cory must have in his repertoire, some convenient categories into which he can place appropriate items on the list. These categories must also be ones that Cory can easily recall... (Mulcahy et al., 1986, p. 12)

For teachers to make effective use of learning strategies they must make students *aware* of their own thinking and ability to gain and maintain control over the learning process. The ability to be aware of one's own thinking processes is often referred to as *metacognition*—the awareness of oneself as an active agent in the process of knowing (Brown, 1980). In fact, many of the thinking skills described in this book are metacognitive in nature because they are aimed at increasing students' awareness of their own cognitive capabilities.

METACOGNITIVE SKILLS AND STRATEGIES

Did you ever notice that students differ in their approaches to learning and problem solving? There are those who can intellectually engage themselves in their work by raising questions, seeking to clarify the meaning of a problem, and analyzing different solutions. Other students seem to lack awareness of how to solve problems and seldom, if ever, seek to clarify or exchange information with other students. They do not follow directions well and have little motivation for doing anything more than taking a shortcut to find the answer (Babbs & Moe, 1983).

Research has shown that students who are able to take charge of their learning have usually acquired self-management skills for thinking.

These children realize that "thinking hard" does not ensure their success in learning. "They begin to restructure messages, ask questions, anticipate outcomes and consider the other person's point of view deliberately and strategically" (Paris & Lindaeur, 1982).

Students such as these who are able to understand and control their own thinking processes are showing evidence of metacognition (Reeve & Brown, 1985). This includes many specific skills in:

- analyzing and characterizing the problem.
- reflecting upon what one needs to know in order to arrive at a solution.
- devising a plan for attacking the problem.
- checking or monitoring progress (Brown, 1978).

Metacognitive activities can be broken into two main categories: (1) activities concerned with conscious *reflection* of intellectual abilities and (2) activities concerned with cognitive *self-regulation* during attempts to learn or solve problems (Brown, 1978). For instance, a student may be able to detect and describe Logo programming errors yet lack effective strategies for fixing and checking these bugs.

In this book, we use *metacognitive skills* to mean both reflective and self-regulative activities. At a basic level, the reflective activities include skills in observing, describing, predicting, and comparing events (exploration). The self-regulative activities involve higher level skills in analysis, planning, questioning, and self-monitoring (see Table 2). In practice, it is often difficult to sort out these two types of activities as they are not really separate categories, but different stages of thinking. Accordingly, we prefer to use the term *cognitive self-management* to stress learner control and independence in thinking.

The Main Types of Metacognitive Skills

- Self-evaluation
- Reflection
- Thinking about thinking
- Analysis and planning
- Self-regulation
- Checking
- Prediction
- Monitoring
- Reality testing

Table 2

The main feature of students who display thinking skills such as those listed above is that they are *aware* of their own thinking and can make *conscious* attempts to control their own problem solving strategies.

Seymour Papert (1980) has probably done more than anyone else in educational computing to popularize the importance of encouraging children to become more aware of their thinking. His main argument for the use of Logo is that it encourages children to "think about their own thinking processes." This is akin with Piaget's view that advanced thinking is marked by the ability of a person to view his or her own behavior as something that can be analyzed (Piaget & Inhelder, 1969).

> *It is this self awareness of one's own mental processes that is most critical for developing effective thinking and problem solving strategies.*

A number of researchers have stressed that students who have difficulty with their learning are likely to benefit from metacognitive training to increase their self-awareness. One approach called "reciprocal teaching" involved teachers and students taking turns in "being teacher" with each participant leading a dialog on a part of the text they were jointly attempting to understand and remember (Palinscar & Brown, 1984). The aim of this approach was to get students to engage in four metacognitive activities considered important for improving reading ability: 1) self-review, 2) questioning, 3) clarifying, and 4) predicting events.

Other researchers have proposed that metacognition and the awareness of self-regulatory activities are based in social interactions with other learners (Vygotsky, 1978). It is through communication with others that children progressively learn how to understand their own cognitive processes and control their own learning.

There has been speculation that computers can be used to boost the development of metacognitive skills. This is because many computer applications are useful for such student-directed activities as checking, planning, predicting, and monitoring. For example, students using Logo are typically engaged in evaluating, debugging, and revising their programs. Word processing provides the context for a very deep and meaningful exploration of the writing process. Databases and spreadsheets naturally provide opportunities for a variety of thinking—predicting, comparing, analyzing, exploring, and evaluating. Later sections of this book illustrate how to promote effective thinking and learning with these specific computer applications.

APPROACHES FOR TEACHING LEARNING STRATEGIES

Traditionally, management of the learning process has been under the teacher's control, not the student's (Pea, 1987). School programs have seldom stressed the *fading of control,* in which learners take over a self-management role from teachers.

What is becoming increasingly apparent is that students need and benefit from explicit support in managing and controlling their cognitive activities in learning and thinking (Pea, 1987). However, such process-oriented teaching has been problematic for classroom teachers. This has been primarily due to a lack of appropriate teaching materials and some confusion about the meaning of transferring control for learning from teachers to students.

More recently, a number of cognitive education programs have been devised primarily for use with students who have learning difficulties (Feuerstein, 1980; Weinstein & Underwood, 1985; Keimig & Carlson, 1983). These programs all provide explicit training of cognitive self-management skills. Stress is placed upon explaining and illustrating how these skills are important for schoolwork and everyday life.

Three approaches to cognitive education have primarily influenced the writing of this book. All are concerned with assisting students to become teacher-independent thinkers:

1. *Strategies Program for Effective Learning and Thinking.* Working with inservice teachers, Bob Mulcahy and his colleagues at the University of Alberta (1986) have devised a strategies program for effective learning and thinking (SPELT). This is based on the philosophy that students need to be presented with highly structured training in order to learn how to use strategies effectively to support their learning.

2. *The IDEAL PROBLEM SOLVER: A Guide for Improving Thinking, Learning and Creativity* (John Bransford & Barry Stein, 1984). This approach is designed to help learners identify the different parts or components of problem solving. Each letter in the word IDEAL stands for a particular part of the problem solving and decision-making process:
   - *I* = Identify the problem.
   - *D* = Define and represent the problem.
   - *E* = Explore possible strategies.
   - *A* = Act on the strategies.
   - *L* = Look back and evaluate the effects of your activities.

3. *Assessing Learning With Logo* (Nolan & Ryba, 1986). Our own work with Logo has been focussed on teacher intervention and the development of six main thinking skills:

1. *Coding*—translating ideas from one form to another
2. *Exploration*—thinking about how something works
3. *Prediction*—thinking about likely outcomes from specific actions
4. *Creativity*—thinking about methods for inventing new products
5. *Analysis and Planning*—systematic thinking and problem solving
6. *Debugging*—checking and self-evaluation

Many activities and suggestions from these three approaches have been incorporated into this book. For more detailed information on specific methods, it is recommended that readers consult the publications cited.

WHY USE COMPUTERS TO DEVELOP THINKING SKILLS?

The educational value of computers cannot simply be measured by the *content* of the software. It is the *process* of teaching and learning that the software employs that largely determines its value. In other words, how children learn is as important as what they learn.

Increasingly, attention is being given to the process of helping children learn how to learn. The basic aim is to assist them in acquiring some personal skills that are needed to be more effective in academic work and everyday life. These personal skills can be summed up as follows (Committee to Review the Curriculum for Schools, 1986):

- **Thinking**—skills of acquiring knowledge, reflection and evaluation, logical organization and presentation of thought, associating, reasoning and creative use of intuition, analysis and problem solving.

- **Expressing**—skills of creating and expressing ideas and responding to the ideas of others in a variety of forms and styles.

- **Relating to Others**—skills of relating to other people in ways that recognize and appreciate the diverse ways of life and the contributions made by different cultures and individuals.

- **Carrying Out Practical Activities and Studies**—skills for learning through carrying out practical tasks, and applying creative ideas to solve practical problems.

These skills can't be taught in isolation, but need to be developed within the school curriculum. The challenge is to find ways of presenting children with opportunities to develop their thinking skills. This is where the computer fits in.

CREATING A COMPUTER LEARNING CULTURE

Creating environments in which effective thinking and learning can take place is the main theme of this book. We believe that too much attention has been given to the technical aspects of computing with little or no focus on the teaching and learning process. Many research articles have not even attempted to describe the type of learning environments that surround the use of computers. They simply say what computer application was used and then ask the question, "What is the effect of the computer on learning?" Questions of this type are largely technocentric because they fail to consider the learning culture. The belief is that the computer is a technical object or agent that can act directly on the child in some way. This type of question largely bypasses the most important components of educational situations—*people and culture*. It may be that students' learning and thinking does change in response to computers. But if you want to understand and influence that change then you have to focus attention on the culture—not on the computer (Papert, 1987).

The study of thinking processes has led to an increasing awareness of the importance of the social and cultural aspects of learning with computers. Increasingly, emphasis is being placed on the teacher and the microcomputer as partners in constructing microeducational learning environments that complement one another and are adaptive to meeting the individual needs of students. One way the computer may be important in this endeavor is by providing the tools and structure for learning, thereby allowing the teacher to engage in interactive, adaptive, and dynamic interactions with learners (Goldman & Pellegrino, 1987).

Effective teacher-computer partnerships need to be formed through a good understanding of the teaching and learning process. They need to be based not only on curriculum materials, but also on methods aimed at developing teacher-independent thinkers. This will require that attention be given to self-management of thinking through reflection and self-regulation activities. The success of such an approach will largely depend on the creation of classroom cultures that are designed for learning.

Each learning culture is different. It emerges in its own way through the interaction of the people and how they use computers. The learning culture is not something that can be defined in textbook terms. It has as much to do with social engagement and sensitivity toward others as it has to do with intellectual and academic development. For this reason, we believe that equal importance should be placed on social *and* cognitive development within the computer environment.

A good example of a computer learning culture can be found within our undergraduate computer education courses. We watch with interest each year as students develop a deep engagement in learning with computers and a strong interpersonal bond with one another. While we provide the facilities, these students form their own culture through:

- *helping* one another to solve problems.
- *openly sharing* information and ideas.
- *reinforcing each other* for making progress in their thinking and programming.
- *working in physically close proximity* to one another.
- *collectively supporting* anyone who has a programming or personal "crisis."
- *extending their effective working relationships* beyond the computer environment to other courses and social situations.

This interaction creates a definite context within which personal relationships can develop. In their turn, the relationships provide an atmosphere in which students share their best ideas and help each other to resolve learning difficulties. These sharing and helping activities form a basis for the emergence of what can be called a *computer learning culture*.

Computers have had a positive effect on the use of cooperative learning strategies in education (see Male, 1988). They have helped to break down some of the barriers that have had a negative effect on the desire of people to learn. Instead of saying, "Don't make mistakes," "Do your own work," and "Be sure to follow the directions," we can say:

It's okay to:

- "Help and share with one another."
- "Explore and think it through for yourself."
- "Reflect on your thinking."
- "Talk about your problems and ideas."

It is social engagement and opportunity to reflect on thinking that is the essence of a computer learning culture. People encounter computers in a particular way, in a particular relationship to other people, teachers, peers, and friends. It is the way that the computer fits into this culture and how it is deployed that will ultimately determine the effect it has on children's intellectual development (Papert, 1987).

Building Environments for Thinking with Computers

The computer enables us to learn in a far more engaging and interactive way than is possible with conventional methods.

With just about all educational applications, we see that it is possible to pay attention to the processes of thinking and learning instead of just the learning outcomes. For instance, the ability to change text so easily on a word processor means that more time ultimately can be spent on the writing process. The structure and procedural logic of Logo programming makes it possible to present abstract concepts in a way that is meaningful to children. Database management programs provide a way for children to collate, count, select, and process information.

The computer enables us to experiment, plan, test, and evaluate our progress. Because changes can be made and the effects analyzed immediately, we are encouraged to explore different solutions to problems. We learn that making mistakes is okay and that errors can often lead to creative and unpredictable solutions. This is contrary to traditional schooling where we were taught that it is essential to "get it right" the first time. When we work with computers, we naturally learn to reflect on our thinking. We learn that making mistakes is an acceptable part of the learning process and that there are often no definite right or wrong answers. Learner control of this kind is essential for self-management of thinking.

Promoting Effective Working Relationships

Social learning skills are critically important for success in life, and the computer provides an ideal opportunity to promote skills in relating to others. Again, it is not so much the content of the computer software that is important, but the teaching and learning process that is used with the software.

The power of computers to promote effective working relationships was illustrated in a recent Logo project we carried out with young clients at a rehabilitation center. These adolescents had recently "graduated" from work experience classes in the high school and had no place to go. Predictably, most of them had experienced more than their share of failure and had low self-esteem.

We found that at the beginning of the project, students preferred to work alone. Despite our encouragement to do cooperative problem solving with their partner, most depended on the training staff to tell them answers. When given a chance to make something of their own, they turned to the staff for direction. What became clear to us was that these young adults had been told what to do so often that they were now passive, helpless even, and unable to make decisions for themselves.

With a lot of careful intervention and encouragement, we were slowly able to get these people to begin thinking for themselves. This was done through teacher questioning and prompting. For example:

- "It's okay to make mistakes."
- "Check with John to see if you two can figure that one out."
- "Try using a different number for Repeat to see what happens."

By the end of the 8-week training program, several of these learners showed improved ability to work collaboratively. That is, they learned to work *interdependently*—looking to one another as a source of ideas and help with problem solving (Ryba, Bishop, & Bishop, 1988).

Another good example of collaborative learning was at a small rural school. Working in groups, children were collecting information on the Olympic Games. They then processed this information to produce a news bulletin for their classmates and townspeople. The computer helped them to organize information about scores and medals awarded, plus compose text and plan the format of the work they had done.

In this way, the children got the experience of using and creating a database. The whole exercise greatly enhanced their ability to work cooperatively with others—collating information, entering data into the database, analyzing data, writing reports with a word processor, deciding on formats, preparing a newsletter, and having to coordinate their work with one another. There was great excitement in the school and community alike as townspeople waited for the next edition of the Olympic news to roll off the press!

Boosting Internal Control and Self-Esteem

Whether students are, in reality, able to exert control over learning may not be as important as the internal sense or feeling that they have of being in control. Once students develop a stronger sense of being in control, they are more likely to

make gains in mathematics and reading skills. It is this inward sense of control that appears to be vital for improving thinking and learning strategies across academic subject areas (Crandall, 1977).

There is good reason to believe that computers can be used to promote the development of internal control. Some specific features that seem to foster this are:

- the lack of external factors to which students might attribute success or failure.
- one-to-one relationship between the student and the computer.
- freedom to explore without penalties for making mistakes.

We have observed how mentally retarded adults appear to achieve a greater sense of power by exercising control over a microcomputer. Many of these adults have led sheltered lives and have had few opportunities to act purposefully and take responsibility for their own decisions. For these people, whose lives are controlled most of the time by external agents (workshop supervisors, group home parents, bus timetables), the computer provided them with a rare opportunity to work independently. Some students even waited for their supervisors to leave the room before proceeding with their work on the computer.

These individuals tended to perceive themselves as "being in charge" to a greater degree than was customary in a conventional teacher-controlled environment. Furthermore, the relatively impersonal nature of the computer can help promote self-management of learning. Ordinary one-to-one types of tutoring may foster dependency behaviors between the teacher and student (Ryba & Chapman, 1983).

Teachers have reported that computers can have positive effects on social and emotional adjustment as well as the usual academic outcomes (Ryba, 1982). A case study serves to illustrate these interpersonal aspects.

> Martin, a very shy, anxious, nonverbal student found it difficult to communicate with his peers and was subject to ridicule and verbal abuse by students. Upon being assigned to manage the computer, he appeared to develop more self-confidence, as he had an opportunity to demonstrate his technical skills and to assist other students with their work. Martin began to communicate more openly and gained such acceptance by his peers that he was eventually nominated by his class to represent the work experience class on a school-wide committee! (Ryba & Chapman, 1983).

Many other examples could be given here to illustrate the ways in which computers can be used to improve students' personal adjustment. A most salient feature of the computer learning environment is the opportunities it provides for control or self-management by students who have repeatedly experienced failure with past learning.

Developing Adaptive Behavior and Cognitive Skills

Self-directed activities such as computer games, Logo, and word processing are useful for promoting independent thinking. In these computer learning situations, students are required to take control and make decisions for themselves. This stands in contrast to traditional computer assisted instruction (drill and practice, tutorials) where the computer tends to take charge of the learner.

We have watched with interest as mentally retarded adults struggle at the outset to understand the "rules" of computer games and then advance over a series of trials to master the program objectives and achieve scores that would make them the envy of any video arcade enthusiast (Ryba & Chapman, 1983). Observations of these trainees' behavior indicate the development of a new range of skills including planning, anticipating various events, sequencing left and right, executing combinations of movements (moving the cursor and shooting at targets), shifting attention to different relevant cues, and increasing motor speed and coordination.

A case study helps to illustrate how games can be used as a context for developing certain functional skills.

> Mary Anne, a 25-year-old mentally retarded woman, was unresponsive to psychological testing to the extent that she was unable to verbalize or follow instructions as required by the test. Accordingly, she was labelled as severely retarded and unlikely to benefit from formal training. A few weeks later, however, we happened to catch a glimpse of Mary Anne during one of her regular sessions on the computer and noted her obvious on-task behavior. She was playing a space invaders type game and appeared able to understand the requirements of the

task. A closer examination showed that she was able to purposefully interact with the game by: (1) moving the cursor left or right to avoid collisions, (2) firing at moving objects, and (3) making decisions concerning the order in which operations should be performed (Ryba & Chapman, 1983).

It was interesting to observe the difference between Mary Anne's performance in the testing situation versus her performance when interacting with the computer. Clearly, some aspects of her abilities might be underestimated on the basis of test results, whereas her actual performance in a real-life situation using the computer indicated a much higher functioning level.

Several studies have confirmed the value of simulations and adventures as a medium for facilitating reading comprehension, language development, communication skills, problem solving, and creative expression. The decision making requirements of adventure games encourage learners to verbalize about what ought to be entered into the computer. Here is an environment where students can learn high order social and cognitive skills involving resolution, cooperation, and consultation. Adventure games provide a context in which thinking and learning strategies can be purposefully discussed. The content of these discussions encourages students to engage in metacognition—*thinking about what they are thinking* (Ryba & Anderson, 1987).

There are an increasing number of studies that illustrate how computers can be used to help learning disabled students become more effective learners (Goldman & Pellegrino, 1987). Various approaches, including computer games, Logo, computer assisted instruction, and the use of databases, have now been applied as teaching and learning tools with these students. When used in conjunction with appropriate remedial methods, these computer applications may help to promote the development of cognitive self-management skills.

There are many students, learning disabled or not, in regular class situations who could benefit from help with developing more effective thinking skills and learning strategies. Recognizing this, a number of researchers now advocate that metacognitive training can and should be included as an element of any remedial instruction package. Such training is viewed as essential to foster both planning in learning and the ability to transfer skills from one learning context to another (Brown & Palinscar, 1982; Goldman & Pellegrino, 1987).

Empowering the Learner with Computer Microworlds

Microworlds are miniature "worlds" that have a life of their own. A microworld is a bounded place, with rules to operate by and where exploration takes place. Some well known examples of microworlds are Logo and adventure games.

The concept of the microworld was first advanced by Minsky and Papert (1972) to describe the restricted world in which artificial intelligence programs operate. The concept was later extended to explain the characteristics of learning environments in which children with learning difficulties could effectively operate (Adams, 1986). Papert (1980), the inventor of Logo, has described a microworld as:

> "a subset of reality...whose structure provides an environment where learners' cognitive mechanisms can operate effectively. The concept leads to the project of inventing microworlds so structured as to allow a human learner to exercise particular powerful ideas or intellectual skills."

Working with the microworld concept, Sherry Turkle (1985) relates the story of Deborah, an adolescent girl who was withdrawn, lacking self-confidence, explosive and overweight, dependent and unhappy. Deborah, who participated in a school Logo program when she was 11 years old, was shown how to write commands that produced pictures on the screen. Turkle describes how, at the commencement of the program, Deborah spent most of her time trying to get the attention of the teacher and making little progress without supervision and support from others. The big change for Deborah came when she restricted the power of her environment by placing an arbitrary rule that would allow her only one turning command—a right turn of 30 degrees.

> Once she had her rule, Deborah got down to serious work. She drew flowers and rabbits and stars and abstract designs, everything built up from right turns of 30 degrees. "I really liked my rule. It was neat. It was hard. I had to figure everything out. I thought about it all the time. I was the only one who had a rule." Suddenly, she found herself, perhaps for the first time, in a situation simple enough for her to control, yet varied enough to allow for creative exploration." (Turkle, 1985)

A significant feature of Deborah's microworld was that it provided a place where she could control the computer and use it to experience success.

Microworlds hold much promise as a means of developing problem solving and cognitive self-management skills. The main challenge, however, is to create environments so that learning can be brought under the efficacious control of the learner (Goldman & Pellegrino, 1987). This requires sophisticated and "intelligent" hardware and software, and a changing role for the teacher in the learning enterprise.

The teacher's role is to facilitate the growth of a learning culture. In the next section, we describe the main components of this role and give examples of the kinds of methods and interactions between students and teachers that are most likely to foster the growth of teacher-independent thinkers.

DO NOT ASK WHAT COMPUTERS CAN DO TO STUDENTS, BUT RATHER WHAT STUDENTS CAN DO WITH COMPUTERS.

Chapter 2 THE TEACHER'S ROLE IN A STRATEGIES APPROACH

Computer education textbooks are full of information on hardware and software. They say a great deal less about how to teach effectively with computers. An understanding of the teaching and learning processes is absolutely essential to an understanding of how the computer fits into teaching (Van Deusen & Donham, 1987).

To assume that it is the software that does the teaching is an easy mistake to make. The teacher's role is to teach; computers and software simply make that job easier. The teacher's role is to plan for and manage the computer learning environment, and to facilitate and guide the learning that goes on within it. Teachers are also participants in the learning that occurs in their classrooms as they work with their students helping them to achieve their goals.

The situation is summed up well by this quote from the British Microelectronics in Education Project:

> "Hardware without software is just junk but
> Software without Teaching is just Noise."

As with any new instructional material, the teacher must personally learn how to use the software. There are two main parts to this process:

1. learning the mechanics of the program, and
2. understanding the learning objectives of the program (what the program is designed to teach).

The first part is usually straightforward. This involves spending some time using the software, reading any accompanying material, and learning to work the mechanics of the program—choices, levels, and help facilities. The second part involves studying what the program teaches and how the teacher can help to facilitate this learning (Van Deusen & Donham, 1987). There are several points to consider:

- What are the learning objectives of this software?
- How does this software fit into the school curriculum?
- What sort of knowledge do students need to use this program effectively?
- Does the software lend itself to individual or group learning activities?
- What specific skills does the software intend to teach?
- What model or approach does the program use for teaching skills?
- What questions does the teacher need to ask to help students to develop the intended skills?

This second component—the teaching component—is often totally neglected. This happens because too many people still believe that software teaches. Teachers teach, and in order to do so effectively, they need to understand how the computer fits into the teaching and learning process.

Using a strategies approach we consider in this section the five main components of the teacher's role as 1) planner, 2) manager, 3) facilitator, 4) guide, and 5) participant. By thinking of their role in this way, we believe that teachers will become more aware of where they are headed and how they ought to intervene to promote the development of effective thinking skills and learning strategies. (See the next page for *The Role of Teacher in Using Computers in Education.*)

TEACHER AS PLANNER

The teacher as planner works to ensure that the computer is properly integrated into the curriculum. Use of the computer is viewed in light of the aims of the school and classroom programs. Appropriate educational software is selected to help meet those aims. This means that the teacher needs to be able to evaluate software packages or at least find out the strengths and weaknesses they have in relation to the aims of the school or class program. A great deal has been written about software evaluation. Without repeating that here, the best methods of evaluation are:

- *Evaluate the software yourself.* There are many different forms that are available for use as guidelines to help you through this process.
- *Consult with other teachers.* Sit down with a teacher who has used the package and find out how effective she or he thinks it is.
- *Read reviews of the software.* Many organizations, as well as magazines, produce reviews of educational software.

THE ROLE OF THE TEACHER IN COMPUTER EDUCATION

Adapted From: Computers In Education Development Unit (1987).

ANY TEACHER WHO CAN BE REPLACED BY A COMPUTER, SHOULD BE!

Remember in an evaluation that there are two views of any educational software package. One of these is the student view—a view of menus, levels, choices, and tasks. The other is the teacher's view, which involves aims, procedures, and follow up. Both need to be considered.

Teachers who choose software to use with the aim of helping students develop their thinking skills may find they have to resolve the conflicting demands of a crowded curriculum and a student's desire to work outside that curriculum.

As an organizer of physical space, the teacher plans a workspace that allows students to work with others both on and off the computer. Students need space to spread manuals, exercise books, drawings, and reference books around the computer in the same way they do when working away from the computer. When students work in groups, as they often will, the need for good planning is immediately evident. A good physical environment helps make certain that students will work together harmoniously.

In many areas, teachers are likely to use group work as the basis of the class program. This is still essential in work involving the computer, despite its appearance as a single-person tool. The importance of collaborative groups is that they allow students to exchange ideas, to support each other during learning, and to discuss possible solutions to problems. As they work together, they need to combine their thoughts to develop appropriate goals; they have to integrate their different views of task performance into a clear plan; they have to evaluate and discuss the results of their work. The job of "driving" the computer is a relatively minor one, easily shared by all. The success of group work often depends on group membership. Although we have all been surprised by students who work well together despite our expectations, most successes come from groups in which teacher planning has played a large part in determining membership.

Planning is an important part of any teacher's role. Here are four main aspects to consider:

- Understand the aims of the school program.
- Select software appropriate for the school and classroom aims.
- Plan for effective computer access.
- Allow for cooperative groups when possible.

TEACHER AS MANAGER

In managing student learning, the teacher has the task of making sure that the learning activities proceed smoothly. When learning involves computers, you must ensure that students get equitable access to the computer(s) and appropriate software. You need to be aware of the inequities that can occur with computer use in your school and actively work to ensure that there are balanced opportunities for all your students to use computers appropriately. You may need to:

- Make sure female students are able to have full and fair participation in computer use. You may need to positively discriminate in order to do this.
- Allow your poorer students to work with software that will help them to develop their thinking skills. Don't always give them another spelling game "because they still need to improve their spelling."
- Be careful that you don't let the advantaged (home computer, summer computer camp, computer user group member) take over.

The introduction of computers to the learning process may also lead to unexpected demands for greater access to other resources. When students work together solving computer "mysteries" (e.g., one of the Snooper Troops series), they may not be content to make notes on pads or in exercise books. You may find it necessary to provide a bulletin board your students can use to exchange information, detail false leads, or leave hints about problems that other groups have yet to face. Students facing the task of database building may want access to information outside the usual school resources such as library books, texts, films, and videos.

Managing learning that involves computer use really asks no more from teachers than that they be flexible and observant.

A brief list of DO's for the teacher as manager:

- DO ensure equitable access to computer resources.
- DO provide the right software for the job.
- DO be aware of possible needs for other resources.

TEACHER AS FACILITATOR

When using computers, the teacher as facilitator will aim to promote learning and the achievement of educational aims by ensuring that software is used appropriately by students. To do so, teachers must understand where the package fits into the curriculum, and they must also be effective users of the software package themselves. When your students have "trapped" themselves within the software, you need to be able to find a way out for them.

This knowledge of software is required in addition to the many other practices that teachers adopt in order to facilitate their students' learning. We shall consider some of the more important practices next.

Support Students as They Learn

In the initial stages of learning, students often need direct help to use new strategies. Simply remembering the information that they are working with may mean that they forget the next step of the strategy. Until new strategies become automatic, students will need some form of support. They may need help in deciding what to do next, or in carrying out a particular operation. Students learning to write and edit Logo procedures are like this for their first few sessions with the editor. They know how the procedure should be programmed, but may forget the END or how to save changes made in the editor. In their enthusiasm for variables in Logo procedures, students using them for the first time may forget to include a variable value when calling the procedure.

Software that provides easily understood HELP screens is useful as long as students know how to access them. But teachers have a store of other methods which can be used to support learners. Some of these are:

- Make wall charts outlining commonly used procedures.
- Provide keyboard outlines for favorite software.
- Have manuals readily available.
- Encourage learners to support each other.

There is a distinction between telling students what to do and supporting their learning. The former places the responsibility for the learning on the teacher, while the latter allows students to maintain control of their learning and to practice and develop the thinking skills that are needed in further learning.

Help Students Set Goals for Learning

Both teacher and student need a good understanding of the aims of the learning situation. This understanding is best achieved through discussion in which students and teachers can question each other and clarify and refine their objectives. Teachers may want to ask:

- "Do you understand what I'm suggesting you do?"
- "Can you tell me in your own words what I would like achieved?"
- "Do you see how this is relevant to your own interests?"
- "Have you ever done anything like this before?"

Questions like these point out to the learner that the teacher's objectives are based on the learner's needs and draw on the interests of learners as a means of ensuring their relevance.

Encourage and Allow Time for Reflection

Students need time. Not only to actually perform the tasks that are important to them, but also to think, to explore, and to be creative within that task environment. Students must be able to discuss with others the way they have carried out certain tasks or why they reached the conclusions they did.

The focus is on the process of obtaining a solution rather than the solution itself. Some good openers for such discussions challenge the students directly:

- "How many other ways can you think of to do this?"
- "Why do both (all) the methods work?"
- "What are the important differences between the ways you solved this problem? Why?"
- "Could the information be presented more clearly?"
- "What were you trying to do?"
- "Is that what you wanted to do?"
- "What do you think you should do next? Why?"

These discussions lead to students checking, evaluating, and re-planning their work. They help students monitor their own thinking and learn effective ways of solving their problems.

Reinforce Correct Behavior and Provide Informative Feedback

Congratulate, thank, and praise your learners for their correct behavior and the attainment of goals. Show your approval when they use a new strategy well, define a procedure in the editor, or change the layout in a database to show relevant fields. Be enthusiastic when they show you how they have planned to solve a problem and when they automatically set about revising plans having discovered a "bug." How many ways can you say "Very Good" when one of your students shows you a newly revised paper they've just taken off the printer? Here are 99 ways. (See next page.)

It is very important that students understand *why* they have done well. One approach is to ask students to explain in their own words why they have done well on a particular piece of work. For example:

- The essay is logically structured.
- The topic is organized into subparts.
- It presents an analysis of problems and then proposes some solutions.
- The main themes are presented at the beginning and then each part is dealt with in turn.
- The essay was carefully checked for errors of syntax and meaning.

Giving reasons helps learners to understand the usefulness of the processes they used in arriving at their solution. As students learn more about the way they think, they are more able to exert systematic control over the strategies they use in problem solving.

Have a Warm, Positive Classroom Environment

Good personal relationships between teachers and students are important in ensuring that learning is effective. The opportunity to form such relationships often arises through the reflective discussions in which teachers participate. By using students' names, by making the time and effort to look at and listen to students as they speak, and by acknowledging student contributions, you will be showing your students that you value them as individuals and as group members.

Focus on Social Competence

A warm classroom environment helps to provide for the social and emotional growth of students. This is especially important for children who have difficulties with learning and/or problems with their personal adjustment.

Teachers can promote affective growth in the computer learning environment by:

- encouraging students to develop close working relationships in which they cooperate and depend upon one another.
- giving students more freedom to move around, to consult with others, and to get help when needed.
- arranging the physical environment to maximize interactions between students.
- observing students interacting and deciding upon methods of intervention that may help to enhance their social competence.
- helping students to accomplish tasks that would be threatening in other noncomputer situations (e.g., serving as a tutor or doing a class presentation).

Our view is that children's self-perceptions of ability and the way they interpret others' behavior toward them have a direct effect on the way they interact with other people. Children with learning problems, for example, often have low academic self-concepts and feel externally controlled by other people. Such children are unlikely to take much personal responsibility in their learning. Fortunately, there are several approaches that can help children to develop their social competence. Chapter 4 offers some strategies for teaching interpersonal and communication skills in the computer environment.

Summary

Using these practices, the teacher as a facilitator can create environments that encourage learning:

- Know the software you expect your students to use.
- Support students as they learn.
- Help students set goals for learning.
- Encourage and allow time for reflection.
- Reinforce correct behavior; provide informative feedback.
- Have a warm, positive classroom environment.
- Focus on social, as well as academic, competence.

TEACHER AS GUIDE

To guide student learning, teachers must draw on their knowledge and understanding of the objectives and capabilities of the software and the school program, and work with students to suggest directions for further learning.

Student learning can often be extended by the way in which teachers provide cues for them. The

99 WAYS TO SAY* VERY GOOD!

1. SUPER GOOD!
2. You've got it made.
3. SUPER!
4. That's RIGHT!
5. That's good.
6. You're really working hard today.
7. You are very good at that.
8. That's coming along nicely.
9. GOOD WORK!
10. That's very much better!
11. I'm happy to see you working like that.
12. Exactly right.
13. I'm proud of the way you've worked today.
14. You are doing much better today.
15. You've just about got it.
16. That's the best you have ever done.
17. You're doing a good job!
18. THAT's IT!
19. Now you've figured it out.
20. That's quite an improvement.
21. GREAT!
22. I knew you could do it.
23. Congratulations!
24. Not bad.
25. Keep working on it, you're improving.
26. Now you have it!
27. You are learning fast.
28. Good for you!
29. Couldn't have done it better myself.
30. You are a joy.
31. One more time and you'll have it.
32. You really make my job fun.
33. That's the right way to do it.
34. You're getting better every day.
35. You did it that time!
36. You're on the right track now!
37. Nice going.
38. You haven't missed a thing.
39. WOW!
40. That's the way!
41. Keep up the good work.
42. TERRIFIC!
43. Nothing can stop you now.
44. That's the way to do it!
45. SENSATIONAL!
46. You've got your brain in gear today.
47. That's Better.
48. That was first-class work.
49. EXCELLENT!
50. That's the best ever!
51. You've just about mastered that.
52. PERFECT!
53. That's better than ever.
54. Much better!
55. WONDERFUL!
56. You must have been practicing.
57. You did that very well.
58. FINE!
59. Nice going.
60. You're really going to town.
61. OUTSTANDING!
62. FANTASTIC!
63. TREMENDOUS!
64. That's how to handle that!
65. Now that's what I call a fine job.
66. That's great.
67. Right On!
68. You're really improving.
69. You're doing beautifully.
70. Superb!
71. Good remembering!
72. You've got that down pat!
73. You certainly did well today.
74. Keep it up!
75. Congratulations. You got it right.
76. You did a lot of work today!
77. Well, look at you go!
78. That's It!
79. I'm very proud of you.
80. MARVELOUS!
81. I like that.
82. Way to go!
83. Now you have the hang of it.
84. You're doing fine.
85. Good thinking!
86. You are really learning a lot.
87. Good going.
88. I've never seen anyone do it better.
89. Keep on trying!
90. You outdid yourself today.
91. Good for You!
92. I think you've got it now.
93. That's a good (boy/girl).
94. Good job, (student's name).
95. You figured that out fast.
96. You remembered!
97. That's really nice.
98. That kind of work makes me happy.
99. It's such a pleasure to teach when you work like that!

When asked, "How are you?" Reply:
SUPER GOOD, BUT I'LL GET BETTER!

*From County of Strathcona's *Teaching Today* Magazine
From Mulcahy, Marfo, Peat, and Andrews, 1986, p. 220

guidance can be very general, extremely specific, or somewhere in between. Students working on a datafile about insects may be trying to find out about what insects eat and why they eat that food. If they are having trouble formulating appropriate questions, a teacher could start by providing a fairly broad cue, perhaps by suggesting a relationship between fields as a starting point for investigation. For instance, the prompt might be:

"Have you thought of relating some feature of the insect to the sort of thing it eats?"

An even more general cue would be to simply suggest:

"Using a database makes it easy to find relationships. Had you thought of looking for any?"

An example of specific help would be to state:

"Look at the insect's habitat and the food it eats and see what relationship there is."

Perhaps the most important test of learning in a computer environment comes when students attempt to apply the skills and strategies they have learned to other situations. The deliberate and mindful guidance of a teacher who can say, *"This is like the time we..."* is necessary for transfer of learning to occur.

Teachers acting as guides incorporate these three elements into their role:

1. They provide appropriate cues for new learning directions.
2. They direct the learner's attention to higher thinking skills .
3. They work with students to apply skills in a variety of tasks.

TEACHER AS PARTICIPANT

It is ideal for teachers and students to work closely together. The computer helps to make this possible through the opportunities it provides for collaborative learning. Here are some principles for working as a participant:

Model Behavior for Students

As a participant, the teacher works alongside students and models appropriate behaviors and learning strategies. Modeling behaviors for students has been shown to be a very powerful way of helping them learn to use new strategies. In modeling, the teacher talks out loud while carrying out the task. The verbalization contains aspects of the task performance (*"I want to delete that, don't I? I have to move the cursor until that whole paragraph is highlighted."*) and examples of the way people evaluate and monitor their thinking as they work through a problem (*"Have I got everything I want highlighted? I need that bit too. I'll go carefully along the line to get it. Good, got it. Now, check once more before I press return."*). When students take their turn, they also need to talk out loud for awhile. This makes it easier for them to check their progress through the task.

Learning behaviors are not the only ones teachers should be modeling. In accepting that on occasion students will know more about the software than they do, teachers can model the flexible, adaptive behavior required of group members. They should provide good examples of the social side of group learning as they work with their students. They need to show sensitivity, provide encouragement, and display confidence and interest in the group's work.

Collaborate with the Students

The job of encouraging students to learn new strategies and working with them to do so is made easier when students are accepted as collaborators in the learning process. When students are kept aware of what needs to be achieved and why, they are willing to become involved in the development of their own thinking skills. Asking questions is a good way to encourage students to reflect on their thinking.

- "What are you doing?"
- "How does that tie in with your goals?"
- "Should we rethink the aim of this session?"
- "Has something more important emerged from your work?"
- "How do these new aims relate to your old ones?"

Questions such as these enable students to refocus on their goals. It provides teachers with an opportunity to discuss with students the ways in which students are using their thinking skills and to talk about the conditions in which they find using particular strategies an easy or difficult task.

Involve Your Students

So far we have stressed the role of the teacher and the questions and actions that a teacher can use as students learn with computers. While we've outlined an active role for the teacher, the mindful active participation of students in the learning process is even more important.

Remember:

- Have your students' fingers on the keyboard, not yours.
- Allow plenty of time for discussion and questioning.
- Use the student's ideas as the basis for further work.
- Listen to your students as they explain their work.
- Provide a good mix of verbal, physical, and intellectual activity.

Summary

This last aspect of the teacher's role brings teachers right into the learning process. The teacher as participant needs to:

- Model good learning and social behaviors for students.
- Help students to verbalize their thinking processes.
- Collaborate with students as they learn.
- Involve the students in their learning.

We have presented five parts to the role of a teacher. Within each of these there is a range of questions, suggestions, and activities that can be used to ensure that the potential existing in computer environments is translated into actual student learning. Most of the approaches presented in this section can be used with any educational computing application. In the next chapter, we will look at some specific approaches for teaching thinking skills in the computer environment.

Chapter 3 STRATEGIES FOR TEACHING THINKING SKILLS WITH COMPUTERS

The aim of a strategies approach is to directly teach thinking skills. This can be done in any subject by teaching *process* as well as *content*. Computers are ideally suited because they help to provide a manageable environment in which the focus can be placed on process—the thinking skills (van Deusen & Donham, 1987).

This chapter describes some methods that can be used for teaching the thinking *process* with computers. The methods are based on sound research and theory and have been used before in cognitive education programs. Many of the approaches presented here are based on suggestions in the *SPELT PROGRAM—A Strategies Program For Effective Learning and Thinking* (Mulcahy, Marfo, Peat, & Andrews, 1986). This approach, which emphasizes the progression from the lowest level of strategy acquisition (teacher-imposed) to the highest level of acquisition (student-directed), reflects our emphasis on creating teacher-independent thinkers.

This chapter is divided into three main sections:

- **Showing Skills and Strategies** explains the importance of teacher-imposed strategies. In the initial phase students need exposure to specific strategies and an understanding of how these can assist with learning.

- **Teaching Skills and Strategies** presents methods for helping students to develop and practice specific skills in exploration, analysis and planning, questioning, and self-monitoring. Emphasis in this section is on shifting the control from teacher-imposed to student-directed strategies.

- **Assessing Skills and Strategies** describes some approaches that can be used by students and teachers to assess the development of thinking skills and learning strategies.

We advocate that thinking skills be directly taught within the computer environment as part of ongoing instruction. In effect, the cognitive instruction approaches presented should become imbedded within the curriculum and within the teaching and learning activities used on and off the computer. Students should also be given practice in transferring skills learned from one situation to another.

SHOWING SKILLS AND STRATEGIES

The aim of this initial phase is to illustrate skills and strategies that students can use in their learning. These may be teacher-imposed and directly taught in order to:

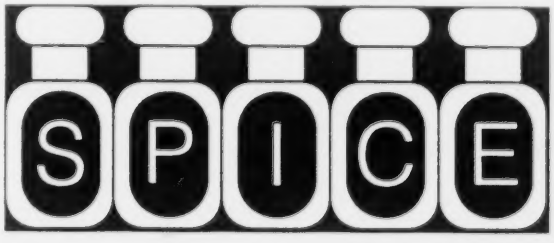
1. Raise the student's awareness that strategies do exist (metacognitive awareness).

2. Provide the language for thinking about thinking (reflection).

3. Promote students' active participation in the learning process (socially interactive learning).

In a thinking and learning strategies approach, the teacher needs to provide constant cueing, demonstration, and reinforcement of thinking skills. This intervention needs to be timely and presented in a way that encourages students to think for themselves. The SPICE model that follows was devised by Bob Mulcahy and his colleagues (1986) at the University of Alberta. It is useful for encouraging students to reflect on their thinking. Emphasis in this approach is placed on showing strategies and getting students to practice using them.

S: Show students some learning strategies that help solve particular problems.
P: Provide key step in the strategy, model the strategies and drill the students in memorization.
I: Introduce way of applying the strategy.
C: Contribute feedback to the students in general discussion and individual basis.
E: Enable students to practice strategies.
(From Mulchay, Marfo, Peat, and Andrews, 1986, p.72)



Show the students some learning and thinking strategies and how these will be applied to solve particular problems. For instance, when working with a database, we encourage students to explore the data for themselves. The teacher then works alongside students, solving problems and illustrating approaches for examining the data. For example, students first explored a file on native trees on their own and then worked with the teacher to examine relationships (e.g., tree height and leaf size). The teacher illustrates how to arrange the data categories and how to use commands to look for trends. Teachers and students then share and discuss their findings.

Ensure that your students have had lots of practice, active involvement, and interaction in using specific strategies. For instance, we frequently remind our students that, "When you try to solve a complicated problem, it is useful to break this problem down into smaller subproblems and then solve these simpler subproblems one by one." Structure diagrams are a good way of illustrating this task-analysis approach (see the word processing section for an example).

Provide key steps in the strategy that help promote the students' understanding. Students cannot become effective problem solvers unless they develop some metacognitive awareness. For example, the teacher might say:

> "Okay, let's see. What's the first thing that I have to do to solve this problem? One way might be to draw a picture of what I want the computer to make. Then I could work out the commands. I think that I'll draw the picture here and write the commands right alongside so that it is easy to check each of the turtle movements."

In this way, the teacher is able to demonstrate some problem solving strategies and to actively involve students in reflecting on their thinking.

Introduce a way of applying the strategy. In the above example, the teacher introduced students to the idea of writing command combinations next to their drawings to make checking easier. The main aim is to use real examples that are meaningful to the students so they can see how the strategy can help them with their work.

Contribute feedback to the whole class, groups, and individual students. The teacher should provide positive and corrective feedback as well as return to verbal rehearsal if the strategy steps are forgotten.

Enable students to practice the strategy by providing a similar problem. For example, students can be given a Logo problem to solve and then be asked to keep a record of their problem solving steps:

- "What step did you do first?"
- "What steps did you do next?"
- "Did you have a plan before you started to make your design?"
- "Did you stick to the same plan from the start to the finish?"
- "Describe in your own words what the five main steps are in planning a design."

Questions such as these provide a good basis for discussing problem solving strategies with the whole class. It is also a good idea to encourage students to talk about their thinking with other students as they actually engage in solving problems on the computer.

TEACHING SKILLS AND STRATEGIES

Teaching Exploration

Exploration is at the heart of the learning process. It provides the *means* through which students first learn to understand and control their thinking skills and strategies. We have observed in our own work that many students do not freely engage in exploration. They need to be encouraged at first and given a free hand to *play* within the learning environment.

The persistent use of exploration over time will significantly affect the quality and worth of all learning that follows. It is for this reason that many writers who are concerned with computers and learning stress the importance of sustained work in this mode. Exploration can, in principle, go on indefinitely, seemingly without result. While learners are preoccupied in this mode, they often formulate questions that pave the way for discovery to occur.

Observing

Logo's popularity as an educational computing language can be attributed to the opportunities it provides for students to observe how their actions directly affect computer outcomes. It is through observation that students begin to form ideas of their own. As the following case study illustrates, exploration may begin at a very basic level, but can soon lead to some very advanced forms of problem solving:

> We used Logo as a way to introduce computers to teenagers attending school at the local prison. At first, we encouraged them

TEACHER INTERVENTION TABLE

TEACHER ASKS	*STUDENT*	*TEACHER FOLLOW-UP*
What did you see (notice, find) here?	Explains his/her in own words.	Reinforces the importance of making observations.
What problems did you come across?	States a problem (e.g., "The turtle disappeared.")	Communicates that it is a good idea to state a problem in your own words.
What questions did you think of when exploring?	States a question (e.g., "How big a square could I make without going off the screen?")	Explains that this type of question leads to important discoveries.

to explore whatever they wanted. One of the first things that they observed was that moving the turtle a certain distance forward or back would remove it from the screen. This paved the way for further exploration to determine how many turtle steps could be taken before the turtle disappeared. Working in pairs, students became intrigued with this problem and worked systematically (doing experiments and keeping notes) to try and obtain information on the characteristics of what became known as *turtle space*. When asked why they were so interested in the turtle space problem, the students explained that, like themselves, the turtle was locked into a certain space and couldn't escape! (Nolan & Ryba, 1987)

Learning to observe is virtually fundamental to all forms of learning, on and off the computer. The teacher's role is to encourage students to become systematic observers rather than impulsive keyboard manipulators. At the same time, care must be taken not to stifle the exploration process by interfering with student-directed activities. One approach is to organize a lesson into three parts:

1. Brief students on what to do.
2. Let them explore for themselves.
3. Ask them to talk about their findings.

Describing

Describing is a natural extension of observing. The aim here is to give students a chance to talk about their findings in a way that is clear and meaningful to them. Learning to articulate problems and ideas can be a major accomplishment for many students. The cooperative learning strategies presented in the next chapter can be very useful for assisting the development of these communication skills. Teacher intervention should take the form of questions and prompts that support students' self-descriptions: (See *Teacher Intervention* table above.)

It is best to ask students open-ended questions about their observations or experience. Providing lots of practice in describing at this basic level can help to promote more complicated types of communication later on. It also helps students to build their confidence. Describing often works best when students are asked to work in teams to explore specific aspects of the learning environment.

Predicting and Explaining

Students can draw upon their descriptions to predict and explain certain events. The greater the amount of exploration that students have had, the greater the likelihood that they will arrive at accurate explanations of what is happening. Asking students to make predictions also leads to some very interactive class discussions. Suggestions for assisting students to develop their prediction skills are given for each of the computer learning applications in the following chapters. In any case, the teaching strategy consists of asking questions such as the following: (See *Predicting and Explaining* table on the next page.)

Encourage students to actively participate in explaining and predicting. Accept diverse responses and have students try out different approaches to problem solving. Positively reinforce all opinions that students advance, whether you think these are correct or not.

PREDICTING AND EXPLAINING TABLE

TEACHER ASKS	*STUDENT*	*TEACHER FOLLOW-UP*
What do you think would happen if...?	States prediction.	Accepts prediction and encourages additional comments.
What makes you think that would happen?	States explanation.	Accepts explanation and asks for clarification if needed.
Lets try that out to see what happens.	Tries out the problem (e.g., Logo procedure or database enquiry).	Confirms student's prediction is correct or asks how the outcome Is different from what was predicted.

Comparing and Contrasting

Students' predictions provide the context for comparing and contrasting different explanations or problem solving approaches. The aim here is for students to identify similarities and differences in explanations. Students should always be encouraged to fully explain their views and to think through the proposed solutions. For example, in an adventure game situation the following interaction might occur: (See *Comparing and Contrasting* table below.)

These basic exploration skills are intended to lay the foundation for more complex types of problem solving. In fact, exploration and the related skills discussed here are part of an ongoing process. It is essential, however, for students to gain some experience and confidence in talking about their own thinking.

COMPARING AND CONTRASTING TABLE

TEACHER ASKS	*STUDENT*	*TEACHER FOLLOW-UP*
How did you work out the solution?	Explains how.	Verifies correctness of the answer and encourages other students to respond.
Did anyone have a different way of	Brings in a new solution.	Confirms both answers are correct and encourages comparison.
How are these solutions the same and how are they different?	Explains.	Encourages diversity by confirming that there is more than one solution to a problem.

Teaching Analysis and Planning

In this section, we discuss the more formal stages of problem solving: identifying, defining, and analyzing the problem; generating alternative solutions; and decision making. It is stressed that these skills should be directly taught within the computer application and subject area. Some material in this section is based on suggestions contained in *The Ideal Problem Solver* by John Bransford and Barry Stein (1984).

Identifying the Problem

The ability to identify that a problem exists is perhaps the most basic characteristic of the successful problem solver. Too often students are given a problem or some work to do without a chance to decide for themselves what the nature of the problem is. For instance, some teachers might tell students to work on Logo projects (e.g., draw a person, a truck, or a tree), while others will suggest students use some shapes they have already drawn (e.g., circle, rectangle, square) to create a design or drawing of their own. In the latter case, students are given the opportunity to frame the problem in a way that is meaningful for them.

- "Gosh, I want to make a truck using rectangles and circles."
- "What design can I think of that would use squares and circles?"
- "The problem is that I need some way to keep track of my moves in this adventure game."
- "The problem is that I have to find some way to introduce the main character of my story."
- "The problem is that I have to figure out a way to get a budget surplus next year."

At this level, the aim is for students to realize a problem exists and to be able to state the problem for themselves. An important aspect of active engagement is that students come to recognize that they are instrumental in selecting effective problem solving strategies.

Students need to think about their thinking through:

- class discussions to identify potential problems.
- teamwork to frame the problem in their own words.

Students who are working with a computer simulation like *Selling Lemonade* quickly realize that unless they balance the expenses with their sales income, they will soon be out of business. This kind of simulation can be used with individuals, groups, or whole classes to get them to focus on the importance of identifying problems.

Self-questioning strategies are a good way to encourage students to actively participate in the identification of problems. Ask questions that require students to state the problems for themselves. For example, "What do you think the problem is with this one, John?" or "Can you tell me in your own words what the problem is?" The aim in asking these questions is to encourage students to reflect on their thinking. Beyond this, it is essential to provide opportunities for students to verbalize what they are thinking. Because most students are unaccustomed to talking about their thinking, it is important to encourage this in every possible way.

Defining the Problem

In a recent study with junior high students, we asked them to do some networking problems—joining dots to make line drawings without lifting their pencil from the page. We asked, "What do you need to know in order to figure out how to do this?" Generally, there were two types of students—those who suggested effective strategies, and those who couldn't really define the problem for themselves. Students who came up with effective strategies answered, for example,

- "Find the best place to start."
- "Trace it with your finger first."
- "Think of a way in your mind."
- "Try different paths until you find one that works."

Those who couldn't really define the problem for themselves gave answers such as

- "Start here and just keep going."
- "Join the dots."
- "Do this part first."
- "Make sure you have straight lines."

Having accurately defined the problem, the first group of students would stop to think about how to do the problem first. They would talk to themselves, trace around the network with their finger, and try different starting places. Having worked out a suitable path, they would then take their pencil and draw connecting lines between the dots.

The second group of students, lacking a clear definition of the problem, would begin at once to join the dots and soon run into trouble. They usually did not study the problem ahead of time and never tried alternative solutions.

What this shows is that the ability of students to define a problem accurately is a vital step in effective problem solving. Often this ability does not come easily. Students need practice in framing a problem in terms that are meaningful for them.

Most theorists generally agree that effective thinking involves the ability to define a problem accurately for oneself. This does not mean just saying in simple terms what the problem is. Rather, it requires explaining it in clear terms so that an appropriate problem solving strategy can be selected.

Students need to learn how to define problems. Teachers need to provide opportunities for this learning to take place within the context of the curriculum. To do this job well, teachers need skills in observing, asking questions, and generally creating a socially interactive and reflective learning environment.

Analyzing the Problem

Most researchers agree that analysis and planning skills do not always occur automatically. They need to be taught and practiced. Logo is ideal for this because of the structure it provides. In our own courses, we encourage students to follow the four main steps in analysis and planning:

Step 1: **Understand the Problem—Define it for Yourself.** Make a drawing of the proposed project. Describe the main parts that are needed and how these might be put together.

Step 2: **Make a Plan—Act on Your Ideas.** Write a procedure you think will tell the turtle how to make the project.

Step 3: **Carry out the Plan.** Type the commands into the computer and then draw a picture of what the turtle did.

Step 4: **Look Back and Study the Effects.** Decide if the turtle did what you wanted it to do. If not, go back and make changes.

These steps may not be so clear-cut as they appear. This is because students are likely to be continuously involved in acting on plans and looking at the effects. In fact, some of the most original ideas come from creative experimentation. An example of this is when making a mistake leads to unintended results, but the effect is good.

It is the teacher's role to highlight and discuss the main components in problem solving. Get students to talk about the steps they go through when solving problems. As a class project, ask students to prepare a thinking skills checklist for the class. Ask them to describe what methods they find most helpful. Descriptions might include:

- Take time to think through a problem.
- Be systematic in working on problems.
- Work out a general plan of attack.
- Evaluate plans and make changes as needed.
- Try alternative ways of approaching problems.

Students need to be encouraged to talk about methods and problems they encounter in planning their work. However, there are no clear-cut right and wrong ways to plan. The kind of planning that students engage in will vary a great deal. Some students, for instance, are *top-down planners*. They begin with the whole problem and progressively analyze it into steps. In contrast, *bottom-up planners* are those who begin with the separate components and build up toward the final solution. In Logo, for example, a top-down planner who is asked to draw a car might begin with a superprocedure (car) and then start to work on subprocedures (body, wheel, bumper). The bottom-up planner might start to first work on each of the subprocedures and then find some way to bring these all together into a superprocedure.

The important consideration is that students have some effective and systematic way of planning that works for them. Some students work best in a situation where they have detailed and ordered written plans. Others will use notes to outline their ideas, but do little formal planning. Others will plan in a spontaneous way by following the "insights" that develop in their minds. Any one of these methods can be effective, but not for all students. Many learners will need guidance and direction to learn the methods of planning that are effective for them.

The ultimate aim is for students to adopt a comprehensive approach to problem solving. The following illustration shows how the four main steps of problem solving can be linked into a continuous and ongoing process. Such a process is applicable to any computer application whether it be writing, programming, building a database, or solving an adventure. (See *Four Main Steps of Problem Solving* on the next page.)

1. Understand the problem

2. Make a plan to solve the problem

3. Carry out the plan

4. Look back to evaluate the solution and make changes if necessary

An illustration based on a problem-solving model by Polya, G. (1957). How to solve it: A new aspect of mathematical method (2nd Ed.). Garden City, N.Y.: Double-Anchor.

Options for Problem Solving and Decision Making

Jim McCauley (1984) describes how he worked with a small group of students to translate the laws of planetary motion into Logo procedures. The article illustrates vividly the many ways in which children can explore the concepts lying behind a particular topic in order to figure out what the *best* way of solving the problem would be. When the students were stuck trying to work out the effects of both inertia and gravity on their turtle satellite, they first explored their ideas and how they might be combined to form a solution by "playing turtle." Having provided initial ideas, this led one of the group members to suggest a way of forming the procedure. Even more discussion and exploration was necessary as that suggestion was refined and eventually translated into code.

> Once the others understand what Carlos has in mind there is debate about which force should act first. Arthur, Peter and Gloria think it should be inertia first, gravity second. Annie is convinced that it should be the other way around, and Carlos is sure that it doesn't matter. We decide to go with the majority (p.20).

McCauley's article also shows how persistence and continued analysis of the problem can eventually lead to that terrific solution mentioned earlier. McCauley's students, having coded the procedures to set the turtle in motion around a "planet," were faced with a turtle-satellite that careened around the screen in anything but a nice elliptical orbit. As McCauley writes:

> It isn't working. And I'm thinking about an early dinner and all the packing I have to do. Annie is staring at a hole in the chart on the wall still covered with sketches from last week. Suddenly she launches herself off the floor like a rocket with a shriek that causes us all to snap our heads about in her direction. "I knew I was right! I knew it!" Carlos is the first to react. "Aw, come on. I told you it doesn't matter if it does the inertia first or the gravity free-fall first. It all comes out the same." "No! No it doesn't. Listen to me! Look up here! Watch!"

The article as a whole indicates the high level thinking that can occur when students work together to analyze problems and plan solutions. Not only did the students analyze things through physical movement, they also drew sketches of their ideas, discussed and debated the various possibilities, and verbalized their thoughts both in planning and in justifying any conclusions or decisions they had reached.

In analyzing the ways problems can be solved, children in a computer learning environment will also be exploring the way they solve problems best. They will find out which problem solving strategies work best for them, how they like to go about solving problems, and how they best interact with other people. As Scardamalia and Bereiter (1982) have pointed out, students are very interested in their cognitive processes. One of the best means of opening up some of these processes to inspection is for the students to think aloud as they are working. Processes that were formally covert can thus be examined and explored more freely as students work toward a better understanding of their cognitive capabilities.

Teaching Questioning Strategies

The ability to ask questions is an important skill for all students to learn. Yet many students lack experience in asking the right kinds of questions. In this section we present some methods that can be used to help students develop effective questioning strategies. We advocate that teachers encourage students to ask questions aloud and talk about their problem solving. This type of self-talk can help to improve a learner's performance.

Computers are ideally suited for learning to ask questions. The interactive nature of the computer provides an ongoing context for asking questions and engaging in self-talk about problems encountered. It is the teacher's role to guide students to ask the right kinds of questions. Torrance and Myers (1970) have identified four main types of questions:

1. **Questions regarding procedures**
   "Does the word processing assignment have to be printed out in letter quality type or is a draft okay?"

2. **Questions regarding tasks**
   "How can I write a superprocedure for this project?"

3. **Questions regarding information**
   "Is this the right menu for deleting files from my disk?"

4. **Questions regarding understanding**
   "What is the similarity between this project and the one we did yesterday?" "Can I use some ideas from the other datafile we constructed?"

Not all students have been taught to ask questions such as those posed above. The aim is to provide lots of opportunities for students to develop their questioning skills and receive approval for the progress they are making. It is important for teachers to engage students in asking questions and to model various types of questioning approaches.

Alley and Deshler (1979) have recommended several techniques to increase the questioning strategies of students. Here are some methods that teachers can use in the computer environment:

1. **A version of the Ten Questions game** can increase the frequency and type of student questions. Pose a problem for students, and then ask them to quiz you on how it was solved. For instance, a Logo procedure or adventure game would be ideal. Respond only "yes" or "no" to student questions until the problem is solved.

2. **Ask students to list the questions** that will be most critical to ask before beginning to write a story on the word processor.

3. **Ask students what questions they will need to ask** before beginning to work on a database project in social studies.

4. **Teach students to use paraphrasing** to clarify their understanding of what someone else has said. Ask students to restate in their own words what another person has said. Teach students to use lead-ins to paraphrasing, such as "I understand you said..."

In summary, it takes time for students to learn to ask good questions. This is especially true for students who have learning difficulties. The main point to remember is that students need to be encouraged to ask questions and to engage in self-talk that will help them to solve problems with and without computers. The main advantage of computers is that they empower learners to ask their own questions and check their own answers. The teacher needs to provide a socially interactive and reflective atmosphere in which the development of questioning strategies can occur.

Checking and Regulating Activities

Computers have highlighted the importance of students learning to monitor their own performance. Self-monitoring is required for students to be effective in working with computers. It cannot be assumed, however, that students already have methods for systematically monitoring their work. Many students may lack this ability and have little knowledge about why or how to check their own work. A key part of this is teaching students to pay attention to feedback received.

The ability to monitor one's own performance is at the heart of a strategies approach. For students to be effective in learning, they need to know how to seek and make effective use of feedback. A valuable characteristic of computers is that they are extremely good for providing students with continuous feedback. It is important for teachers to encourage students to make effective use of this feedback and to get into the habit of regularly checking their work. Some techniques that can help students to check their responses more carefully have been suggested by Alley and Deshler (1979). Here are some ways to apply these in the computer environment:

1. **Don't assume that all students know how to monitor their performance.** Observe students who seem to have difficulty and target them for future intervention work. Spend time on a one-on-one or small group basis showing these students how to check their work. For instance, show them strategies for locating bugs in Logo. Work alongside them when they are proofreading their work.

2. **Set aside a certain portion of each session for checking work.** This can be done formally with the whole class, or informally by prompting students who need to be reminded to check their work. Build checking activities into your ongoing teaching approach. Ask students to stop and check their work before proceeding to the next stage.

3. **Provide students with general feedback that encourages them to monitor their own performance.** For example, a teacher might say, "How can you check to see if that is correct?" The aim is to get students to locate and fix errors for themselves, rather than having them rely on the teacher to do so.

4. **Reinforce students for engaging in self-monitoring activities.** Use verbal praise on a one-to-one basis and give written feedback on hardcopy assignments.

Evaluating and Revising

Looking back and being able to evaluate one's own solutions is a very important part of effective thinking. Unfortunately, many students have been conditioned to believe that they must always try to get something right the first time. These students have been taught that making mistakes is unacceptable. An important contribution of the computer in education has been to demonstrate that it is okay to make errors—that making mistakes is a natural and often creative part of the learning process. Teachers can help by providing the conditions students need to engage in learning with computers as a natural and enjoyable process.

Encouraging students to look back and to engage in self-evaluation is a vital part of effective problem solving. The ability to ask questions such as:

- "Am I on the right track?"
- "What will happen if I make these changes?"
- "What is another way I can do this?"
- "Is it worthwhile to change this or should I start again?"

may lead to more efficient ways of solving a problem. This can be both painful and rewarding.

Problem solving is a continuous and ongoing process as illustrated by the following spiral model of problem solving. As the model shows, it may be necessary to revise a plan several times. In each cycle, observation and reflection play an important part. The computer's power is that it enables learners to progressively work through the cycle—modifying and evaluating their ideas.

ASSESSING THINKING SKILLS AND STRATEGIES

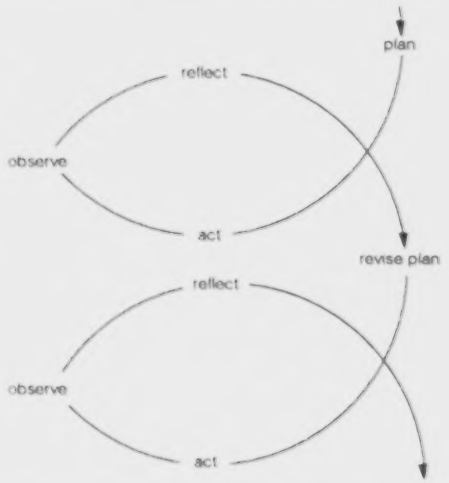
Teachers can gain a great deal of information on students' thinking skills by carefully observing and informally assessing students' performance in the classroom. The best and most effective assessment methods are those that can be used informally by teachers as they interact with students on a day-to-day basis. Formal objective tests, which compare a student with his or her peers, are not usually very helpful. Assessment methods should guide instructional decision making as it takes place in the classroom from moment to moment (Johnston, 1987).

In this section we provide some examples of approaches that can be used for assessing thinking skills. Teachers are encouraged to develop and refine their own methods.

Checklists

Checklists can help make observation more systematic and meaningful. The aim is to identify behaviors that are observable and reflect underlying thinking processes. The following set of questions can be used to determine a student's readiness to apply problem solving skills in the computer environment. The teacher may rate the student on each item by using a scale of 1 to 5, with 5 indicating mastery.

SPIRAL MODEL OF PROBLEM SOLVING



THINKING PROCESSES CHECKLIST

	Not Mastered				*Highly Mastered*
1. Does the student know how to break down complex problems into smaller and simpler subproblems?	1	2	3	4	5
2. Can a student clearly explain in his or her own words what the problem is?	1	2	3	4	5
3. Does the student know how to make use of books and manuals to help work out a solution to a problem?	1	2	3	4	5
4. Can the student discriminate between what is relevant to the problem and what is irrelevant?	1	2	3	4	5
5. Does the student try different approaches to solving a problem and evaluate the effect of each approach?	1	2	3	4	5
6. Does the student demonstrate pre-planning (keeping notes, talking about solutions)?	1	2	3	4	5
7. Does the student evaluate his or her work—selecting and rejecting aspects after a critical appraisal?	1	2	3	4	5
8. Can a student use a systematic method for locating and fixing mistakes before changing plans?	1	2	3	4	5

In our work with Logo, we designed checklists that teachers could use to assess thinking skills at each Logo level (Nolan & Ryba, 1986). These help to determine if a student has developed specific thinking skills. For example, if a student is not showing self-evaluation then the teacher could focus on this aspect. Following is an example of one of the checklists. (See next page.)

DEFINING PROCEDURES
THINKING PROCESSES CHECKLIST

NAME: _____ **DATE:** _____

SCHOOL: _____ **CLASS:** _____

INSTRUCTIONS: Place the code letter which best describes the development of a particular thinking process alongside each item in the ASSESSMENT column.

M = Learner has mastered and consistently demonstrates this process.
P = Learner has only partially mastered or inconsistently demonstrates this process.
N = Learner has not yet developed or demonstrated this process.

CODING	THINKING PROCESSES	ASSESSMENT
	1. Remembers the commands needed to enter and leave the procedure writing mode.	_____
	2. Writes simple procedures from given sets of basic Turtle commands.	_____
	3. Translates plain English commands into sets of basic Turtle commands and writes these as procedures.	_____
EXPLORATION	1. Makes variations to basic procedures by altering command combinations and input numbers.	_____
	2. Compares the outcomes of procedures which contain different command combinations and input numbers.	_____
	3. Experiments by using a procedure with other commands and command combinations (e.g., REPEAT statement) to produce complicated patterns.	_____
PREDICTION	1. Specifies what shapes and designs will be produced by given procedures.	_____
	2. Estimates size and proportion of drawings which will be produced by given procedures.	_____
	3. Describes the outcome which will result from using a procedure in combination with other commands.	_____
CREATIVITY	1. Invents own designs and patterns by using a procedure.	_____
	2. Devises own patterns or designs by using a procedure in combination with other commands.	_____
	3. Constructs geometric shapes and designs by using combinations of two or more procedures.	_____
ANALYSIS AND PLANNING	1. Devises a plan for writing a procedure which will make a given design.	_____
	2. Identifies the main problem solving stages for making a procedure which produces a specific drawing or shape.	_____
	3. Devises a plan which uses a procedure to construct own drawing and describes the main steps in planning.	_____
DEBUGGING	1. Identifies and fixes simple bugs (syntax errors) in a given drawing produced by a procedure.	_____
	2. Locates and corrects logic (programming) bugs in a given drawing produced by a procedure.	_____
	3. Connects the idea of debugging real life procedures with debugging Logo procedures.	_____

COMMENTS

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Reprinted from *Asssessing Learning With Logo* by Pat Nolan and Ken Ryba. Eugene, OR: ISTE p.83

Another approach that is easy and very quick to administer is a checklist about students' own perceptions of their thinking ability. Questions can easily be added and adapted to make them relevant to a particular situation.

STUDENTS' PERCEPTION OF THINKING SKILLS

Read each of the following questions. Decide whether the question describes you. Then check YES or NO or UNDECIDED to indicate your answer.

1.	Do you see yourself as one who likes to work on a problem until you solve it?	Yes	No
2.	Do you think that a computer can help you learn to become a better problem solver?	Yes	No
3.	Do you like to talk with other people about work you are doing on the computer?	Yes	No
4.	When you encounter a problem on the computer, do you try different ways to solve it?	Yes	No
5.	Do you take time to think about your ideas before putting them on the computer?	Yes	No
6.	When you get stuck, does it help to explain your own thinking about the problem to others?	Yes	No
7.	Do you talk much with other students about ways to solve problems on the computer?	Yes	No
8.	Do you plan your work in advance, before going to the computer?	Yes	No

Questions such as these can be used to discuss the importance of effective thinking and learning strategies. It is best to actively involve students in the assessment rather than testing them. Teachers and students need to work together to develop a clear understanding of thinking strategies and methods. Questionnaires and checklists can be followed up by introducing students to one of the problem solving methods in this chapter.

Observations and Interviews

The importance of teachers working alongside students has already been discussed. The aim is to ask questions and make students feel comfortable in responding and talking aloud about their work. Peter Johnston (1987) offers several practical recommendations that can help teachers to become "evaluation experts."

1. **Detect Patterns**—The expert watches students for signs of development in prediction, self-monitoring, self-correction, and independent learning.

2. **Know Classroom Procedures**—The expert knows how to set a context in the classroom so that certain behaviors are most likely to occur. This might involve physical rearrangement, scheduling interviews with students, and planning and carrying out observations.

3. **Listen**—Experts know how to listen with appropriate attention, patience, and thoughtful questioning. The teacher strives to understand the child's understanding of the learning process.

4. **Evaluation That Serves Instruction**—Classroom evaluation is process oriented and requires the teacher to adopt the role of an advocate (Graves, 1983). Avoid test-centered

TEACHER ASKS	*STUDENT*	*TEACHER FOLLOW-UP*
Tell me what you think the problem is.	Explains in own words	Communicates that the student provided a clear description of the problem.
What is the first thing you would do?	Restates the general problem.	Teacher seeks clarification, "Okay, but tell me the first thing you would do or look at."
How did you figure out a way around this?	Gives explanation.	"I like the way you checked everything in turn to find the mistake."
How did you check to see if you were correct?	States the things checked.	Communicates that this is good and asks for other things that confirm the answer.

evaluation procedures that cast teachers and students in fundamentally adversarial roles, which preclude effective teaching (Johnston, 1987).

5. **Empower the Learner**—Emphasize the development of continual self-evaluation so that learners may be responsible for and direct their own learning.

6. **Timely Assessment**—The roles of teacher and evaluator allow teaching and evaluation to occur at the same time, while encouraging modeling and independence. Knowledge gained through classroom evaluation will influence a teacher's instructional interactions. The teacher "owns" the information and will be more likely to use it.

Set a task for students (Logo, adventure games) and then move alongside them to talk about their approach to problem solving. The following dialog illustrates the type of interaction between students and teachers that can be effective for assessing and developing thinking skills: (See table above.) There are many types of questions that teachers can ask students to encourage them to reflect on their thinking. The success of these interactions will depend upon the classroom climate. It should be warm and positive with time for reflection and lots of opportunities for collaborative work.

Teachers can use a checklist or running record to keep information on students' learning strategies. The same principles apply for computer and noncomputer situations, but the main benefit of the computer is that it provides the tools and structure for learning. The teacher is then free to interact and work alongside students in a way that is not possible in noninteractive environments.

SUMMARY

The above techniques help students to focus their attention on the learning process as well as the learning product. The overall aim is to have learners impose their own strategies for effective thinking and learning, rather than depending upon teacher-imposed ones. All of the methods for assessing and developing thinking skills in this section can (and should) be imbedded as an ongoing part of the curriculum. Computers naturally lend themselves to the explicit teaching of student-controlled learning strategies in the ways outlined.

Chapter 4 STRATEGIES FOR TEACHING SOCIAL SKILLS IN THE COMPUTER ENVIRONMENT

Early work with computer assisted instruction seldom focused on social aspects of learning. Students worked in isolation on drill and practice programs away from the class. Concern was even expressed that such isolated experiences could be "dehumanizing" in the sense that computers were being used to control student learning. Such fears proved to be unfounded, however, as more emphasis was placed on the integration of computers into the classroom and school curriculum (Collis, 1988). It is now common to see children freely communicating and learning through interaction with one another in the computer environment.

In this chapter, we present some cooperative learning methods that can be used to promote social development with computers in the classroom. In our view, the development of interpersonal skills rates the same importance as academic learning. This is because a student's effectiveness in life will depend as much upon skills in relating to other people as it does on academic skills. The aim in a strategies approach is to directly teach social skills in the computer environment.

Mary Male (1988) has provided a good description of how cooperative learning strategies can be applied in the computer situation to support social development. She indicates that there are three important questions that need to be considered:

1. "How can we use the computer to create positive interactions among students, both regular and exceptional?"

2. "How do we ensure that computer experiences enhance self-esteem of students?"

3. "How should classroom use of computers be organized so that students develop interdependence, good work habits, and a sense of their own competence?"

This is not a separate mission for computer use, but one that can be linked directly to the curriculum and to methods for developing effective thinking and learning strategies. For example, computers naturally lend themselves to cooperative learning approaches. In turn, cooperative learning is based upon the concept of interdependence—students learning and depending in a positive way on one another.

Interdependence is a key element in a strategies approach. This is because there is a crucial link between childrens' social development and their acquisition of cognitive self-management skills. Research evidence now suggests that children learn a great deal about their own thinking through interacting with other learners (Luria, 1976; Vygotsky, 1978). It has also been suggested that the origins of self-conscious regulation lie in the interactions between children and adults (Wertsch, 1985). If this is so, then well-organized forms of cooperative learning that stress interaction should help children to become effective thinkers and problem solvers.

Accepting the importance of interdependence as a goal of education with computers has important implications for practice. First, students will need to acquire (if they haven't already done so) the necessary social skills to operate effectively in interdependent settings. Second, teachers will need to design activities so that each student has an active and meaningful role in the group situation. Third, the competitive classroom structure will need to be replaced with a cooperative learning structure. The computer is ideally suited for making these changes. As we will demonstrate in this section, all of these changes can be made without changing the school curriculum.

CREATING POSITIVE INTERDEPENDENCE

Traditionally, independence has been stressed as a major goal of education. The aim was to make students academically competitive and self-sufficient. Students worked individually toward a goal without paying attention to other students (Johnson & Johnson, 1987). In contrast, the goal of interdependence is for students to feel that they have a vested interest in each other's learning as well as in their own. Instead of competing with one another, students perceive that they can only reach their learning goals by counting on one another. Personal success depends upon the establishment of good working relationships within their learning group. The development of interdependence at school is a natural extension of what already exists at home, work, and in the community—where people depend on one another. Mary Male (1988) has provided examples of five types of interdependence in the computer situation:

- **Goal Interdependence**
  "You won't be finished until every person in your group can explain how to teach the turtle to draw a triangle."

- **Task Interdependence**
  "Each of you will be an expert on a different aspect of the story—one on the setting, one on the characters, one on the plot. You must agree on how to put your story together.

- **Resource Interdependence**
  "I will give only one worksheet to the group. You must record your group's prediction of what the turtle will do on the worksheet."

- **Role Interdependence**
  "Each of you will have a job. One of you, for example, will be the checker. The checker's job is to make sure that everyone can explain how they came up with the answer. I will be giving your group credit for how well each of you does your job."

- **Reward Interdependence**
  "Your grade will be made up of the sum of the individual grades on the test."

The teacher's role is to help students develop a sense of identity and positive dependence upon one another. Group building activities are undertaken to promote the feeling among students that they have a mutual part to play in group performance. These provide opportunities for students to develop a sense of interdependence.

Debriefing is a useful method for uncovering:

- what each person thought they contributed to the group.
- how the group helped each member to learn.
- problem solving approaches the group adopted.
- difficulties the group members had in working together.

There is evidence that computers help to promote cooperative learning. For example, Hawkins, Sheingold, Gearhart, and Berger (1982) observed more peer interaction among 8 to 11 year olds when they were working on a computer than when they were working on noncomputer classroom tasks. Junior high students have also stated a preference for working cooperatively with other people rather than on their own. For example, when working in pairs on adventure programs, these students took turns as recorder and computer operator (Ryba & Anderson, 1987).

DIFFERENCES BETWEEN COOPERATIVE AND TRADITIONAL LEARNING

Many of the best computer uses are those that involve group work. The natural appeal of children working jointly with a computer, coupled with the shortage of hardware in schools, has encouraged the use of collaborative learning activities. It is important, however, that group activities be carefully structured to promote cooperative work and interdependence among students. Johnson and Johnson (1987) have provided a good summary of the differences between traditional learning groups and cooperative learning groups (See Table 1 below).

Cooperative and Traditional Learning Groups: What is the Difference?

Cooperative Learning Groups	*Traditional Learning Groups*
Positive interdependence	No interdependence
Individual accountability	No individual accountability
Heterogeneous grouping	Homogeneous grouping
Shared leadership	One appointed leader
Shared responsibility for other for self	Responsibility only each
Task and maintenance emphasized	Only task emphasized
Social skills directly taught	Social skills assumed
Teacher observes and intervenes	Teacher ignores group functioning
Groups process their effectiveness	No group processing

Table 1

1. Positive interdependence means **learning to rely on others** in the group. In cooperative learning groups, goals are structured so that individuals depend on one another. Students are concerned about the performance of all group members as well as their own. Interdependence can be structured in the ways outlined above (by task, reward, goal, resource, role).

2. In cooperative learning groups, **every student is individually accountable** for his or her own performance. Students are given individual feedback and the group is given feedback on how each member is progressing. Students are encouraged to help and support one another. All cooperative group members are accountable for mastering the assigned task. In contrast, traditional learning groups are not usually held accountable for providing their share of the group's work.

3. Membership in cooperative learning groups is usually **heterogeneous** in ability and personal characteristics, while traditional learning groups are often homogeneous in membership.

4. All cooperative group **members share leadership activities**, whereas in a traditional group someone is appointed to be in charge.

5. In a cooperative learning group, members are **responsible for one another's learning.** They are expected to help and support one another. In contrast, traditional groups are not responsible for each other's learning.

6. Cooperative learning groups have a dual focus on maximizing each student's learning and **maintaining good working relationships** among members. On the other hand, traditional learning groups most often focus only on the completion of assignments.

7. In cooperative learning groups, **skills of collaboration are directly taught** as required. This may include skills in leading, communicating, and organizing group work. In traditional classroom groups, these skills are often overlooked or left undeveloped.

8. A cooperative learning approach requires that **teachers observe the groups**, examine problems they have in working together, and provide feedback on how effective each group has been. In contrast, teacher observation and intervention is not a feature in traditional learning groups.

9. Teachers of cooperative groups offer time and procedures that students can use to **analyze the effectiveness of their group**. This analysis includes an assessment of collaborative skills and the extent to which the learning needs of group members have been met. The group can then plan how to work more effectively with each other in the future.

Teacher observation is a critical part of a cooperative learning approach. An observation schedule such as the one displayed here can be useful for making systematic observations:

OBSERVATION SCHEDULE

OBSERVATION ITEM	*GROUP 1*	*GROUP 2*	*GROUP 3*
Helping and supporting activities			
On-task interaction and conversation			
Approaches for shared decision making			
Organization of tasks to be completed			
Feedback between group members			
Problems in working together			

LEARNING TOGETHER: A COOPERATIVE LEARNING STRATEGY

Learning together is a cooperative strategy that illustrates the key features of cooperative learning in the classroom (Johnson & Johnson, 1987). An explanation of how *learning together* can be applied in the computer environment has been provided by Mary Male (1988):

1. Assign students to heterogeneous teams and do team building as necessary to promote trust and friendship.

2. Present the group goal (the "payoff" for working together).

3. Review the group skill to be emphasized (checking, summarizing, giving feedback to one another, etc.).

4. Make sure that some of the students in each group can operate the software.

5. Explain how each student's contribution to the team effort will be evaluated.

6. Observe the groups working on and off the computer. Keep track of individual achievements, collaborative strategies, and problems experienced by the group in working together. These points should be discussed during the "processing" session.

7. Review the group product.

8. Check for individual participation, understanding, and contribution.

9. Recognize outstanding group performance.

10. Lead the processing discussion.

A more complete discussion of the teacher's role in structuring such cooperative learning activities can be found in Johnson and Johnson's *Structuring Cooperative Learning: Lesson Plans for Teachers* (1984).

Examples of how to create cooperative learning lessons in the computer environment can be found in Mary Male's *Special Magic: Computers, Classroom Strategies and Exceptional Students* (1988).

PAIRED PROBLEM SOLVING STRATEGY

The paired problem solving strategy presented here is adapted from earlier work by Whimbey and Lockhead (1979).

Description

Students are divided into pairs (problem solver, recorder) in order to work together solving problems. The use of a "think-aloud" procedure allows them to see how their partner thinks and solves problems. Their thinking steps are thus open to view and can be observed and communicated. This procedure is used as follows:

1. The problem solver thinks aloud while solving a given problem.

2. The recorder listens carefully, noting the steps to be taken in the solving of the problem. At the end of this think aloud procedure, the recorder may ask clarification questions of the problem solver and/or may point out errors made in the problem solving process.

3. Roles are reversed, repeating the same problem.

4. The teacher then works with students in small groups or with the whole class to debrief about their paired problem solving experiences. The role of thinking and listening are discussed in terms of interdependence and cooperative learning. Effective problem solving strategies are illustrated through the sharing of students' experiences.

You can expand this strategy to involve three people by subdividing the recorder's role into recorder and questioner. The three roles would rotate.

Suggested Applications

The paired problem solving approach can be applied in Logo, adventure games, simulations, databases, spreadsheets, and most other educational applications.

1. The assessment items in *Assessing Learning With Logo* (Nolan & Ryba, 1986) can be used for paired problem solving activities.

2. With adventure games such as *Dinosaur Discovery*, one student thinks aloud while making decisions and solving problems. The other student serves as a recorder—asking questions, drawing a map, keeping records. This approach could be modified to include three students by dividing the role of recorder and questioner.

3. Students using a database can work in pairs or trios in a similar way to that described above. One student serves as questioner and recorder, listening and noting the steps taken in solving problems. For example, she or he might record steps taken to organize the data alphabetically, search for certain information, and select specific records. The other student explains aloud each step in problem solving as they work on the computer. Students rotate roles after a particular amount of time or completion of a task.

Paired problem solving can be naturally built in to most computer activities. Such a strategy has many advantages in classroom learning:

- Interdependence is promoted.
- Listening skills are required.
- Reflective thinking is encouraged.
- Self-talk is necessary.
- Record keeping is required.

THE CHECK APPROACH

As a participant in learning, the teacher should spend time helping students to develop good oral presentation strategies. This can be done through modeling, cueing, and supporting students as they present verbal information to one another. It is often a good idea to shape presentation strategies in small groups before asking students to speak to the whole class. Because students often lack experience and confidence in doing verbal reports, it is recommended that they be given some guidelines on how to communicate effectively with others. The CHECK system presented here can be used to focus attention on important presentation aspects.

Check Presentation Guidelines

C: Checking the audience
—Is everyone ready to listen?
H: Having eye contact with the audience
E: Expressive
C: Clear
—Make sure you speak so that everyone can understand your words
K: Keen to be heard
—Show you're interested in what you're saying; be enthusiastic

Debbie Hamilton—Clamar School, County of Leduc. From Mulchay, Marfo, Peat, and Andrews, 1986, p. 131

Teachers can use CHECK with individual students or the whole class to highlight some important principles to be followed when speaking to others. CHECK can also be used by students to evaluate their own presentation strategies. The aim should be to reinforce effective presentation skills. The approach should be used in a positive way through close collaboration of students and teachers. Don't put students on the spot. Instead, provide lots of encouragement and support to help them gain experience and confidence in doing verbal presentations.

Learning to communicate verbally is more likely to be effective in a relaxed and informal setting (e.g., small groups or pairs) than in a formal and anxiety provoking situation (e.g., class discussions and presentations). As students gain confidence, more demanding verbal presentation tasks can be set for them. The key element of successful intervention is for teachers to work alongside students, involving and helping them to become effective communicators.

SOCIAL PROBLEM SOLVING STRATEGY

A strategies approach can be applied to social problem solving as well as to academic situations. This can be beneficial for students who need help to improve their personal adjustment. Well adjusted students can also benefit through learning how to listen and respond to others' needs. There are many areas of social interaction that can be developed through this approach, for example:

- listening.
- asking for help.
- offering help.
- understanding other's feelings.
- using self-control.
- accepting consequences.
- dealing with being left out.
- dealing with group pressure.

The use of cooperative learning activities in the computer environment can be an ideal way to help students develop in some or all of the above areas. This is because cooperative learning is structured to promote positive interdependence among students.

An approach to social problem solving based on a model by Mulcahy and his colleagues (1986) is presented here. This can be easily applied to the computer situation.

1. Assign students to work in groups of three or four. Ask them to read the following case study while you read it aloud.

2. Ask students to identify the problem. Use the steps in the problem solving model in order to guide students to describe the problem in their own words.

3. Ask students to spend some time (5 to 10 minutes) working out some possible solution strategies. They should keep a note of strategies and possible barriers to solutions.

4. Ask students to write down what they think are the solution outcomes (goals) for this person. Ask students to write down some advice (recommendations) that might help the person to try out the proposed solutions.

5. Conduct a debriefing session to examine the responsibility students have to help one another. Ask students to identify some approaches they could use in their group to positively involve a person with special needs. Make a list of the suggestions for the entire class.

(See *Social Problem Solving* model on page 40.)

Example Case Study

"You find it very difficult to work with others in the computer groups. The students seem to ignore you. They don't ask you to work with them or to use the computer. They are so busy talking among themselves that you seldom have a chance to say anything. When they divide up the work tasks, they always give you the most boring jobs and don't even stop to consider what you would like to do. You prefer to work on your own and are angry that the teacher does not understand this."

(See *Social Problem Solving* worksheet example on page 41.)

Step 1: Identify the Problem

a) What is the problem? (*Being shut out by others.*)
b) Whose problem is it? (*Not sure. Mine or someone else's.*)
c) Does it need to be solved? (*Yes, or I'll leave school.*)
d) How does it make you feel? (*Hurt and angry others don't like me.*)
e) How does it make others feel? (*I don't know. I don't think others care about me.*)

Step 2: Possible Solutions

a) *Ask teacher to help me work in groups.*
b) *Avoid working with other students.*
c) *Remain silent and just ignore others.*
d) *Wait for teacher to ask me to work in a group.*
e) *Try to speak out more and let others know what I think.*

Consequences

a) *Teacher won't like me any more.*
b) *I don't want to work alone.*
c) *I get mad at others when they don't let me speak.*
d) *Teacher doesn't seem to know I exist.*
e) *Teacher might not understand my feelings.*

Solution Outcomes

a) *Be able to speak to others.*
b) *Be able to have turns working on computer.*
c) *Be accepted by others.*

Step 3: Try Solutions

a) *Ask teacher to help me. (Teacher put me with students I find it easy to talk to. It worked.)*

b) *Try to speak out more. (Other students listened to what I had to say. They let me have a turn on the computer. It worked.)*

As can be seen, it is possible to solve social problems in much the same way academic ones are solved. The main requirement is that students be able to reflect on their thinking in order to answer the questions and make choices contained in the model. We believe that a systematic approach to problem solving such as that displayed here can be very useful in all areas of the school program.

SUMMARY

Social development in the computer environment is as important as academic development. The model of learning advanced here is one in which students develop positive interdependence—they learn to trust and depend upon one another. Cooperative learning strategies are ideal for developing interdependence because they emphasize: (1) direct instruction in social skills, (2) respect for persons regardless of abilities or disabilities, (3) effective speaking and listening, (4) shared decision making, and (5) attention to learning processes. Computers are ideally suited for cooperative learning because they provide the context for group problem solving (i.e., assignment to tasks, a common group goal, and immediate feedback). The teacher is then freed to guide students in the development of their social skills and learning strategies.

STEP 1—Identify the problem:

a) What is the problem?

b) Who's problem is it? _____

YES — NO (i.e., someone else's problem)

c) Does it need to be solved? → Why? _____

d) How does it make you feel? Why? _____

e) How does it make others feel? Why? _____

_____

Are there other associated problems to solve?

NO — YES

STEP 2—Possible Solutions:

Consequences

*** Solution Outcomes (Goal)**

Possible barriers to solution.

1a) _____ 1a) _____

1b) _____ 1b) _____

1c) _____ 1c) _____

_____

*Solution outcomes are dependent on personal priorizing of the problems with associated goals.

STEP 3—Try Solutions:

Did it work?

- NO (Due to projected barrier.)
- NO (Due to unpredictable barrier.) → Generate NEW alternate solution. _____
- **YES** (Matches solution outcomes.)

*Solution outcomes are dependent on personal prioritizing of the problems with associated goals
From Mulcahy, Marlo, Peat, and Andrews, 1986, p. 231

STEP 1—Identify the problem:

a) What is the problem? Being ignored by other people.

b) Who's problem is it? Not sure. Maybe mine or someone else's?

YES

c) Does it need to be solved? Yes, or I'll leave school → Why? ____

d) How does it make you feel? Why? Hurt and angry others don't like me

e) How does it make others feel? Why? I don't know

I don't think other people care about me.

NO (i.e., someone else's problem)

Are there other associated problems to solve?

NO

YES

STEP 2—Possible Solutions:

Consequences

*** Solution Outcomes (Goal)**

Be able to speak to others.
Be able to have time on computer.
Be accepted by others.

Possible barriers to solution.

1a) Ask teacher to help me work in groups.
1b) Remain silent. Ignore others.
1c) Try to speak out more and let others know what I think

1a) Teacher might not understand my feelings
1b) I don't want to work alone
1c) I get mad at others when they don't let me speak

*Solution outcomes are dependent on personal priorizing of the problems with associated goals.

STEP 3—Try Solutions:

Did it work?

- NO (Due to projected barrier.)
- NO (Due to unpredictable barrier.) → Generate NEW alternate solution.

• YES

(Matches solution outcomes.)

*Solution outcomes are dependent on personal prioritizing of the problems with associated goals.
From Mulcahy, Marfo, Peat, and Andrews. 1986. p. 231

Chapter 5 LOGO AND THE DEVELOPMENT OF THINKING SKILLS

WHAT IS LOGO?

Logo is a programming language, but its use in education can be seen as much more than that. It combines:

- An easily accessible programming language.
- A view about the learning process.
- An educational philosophy about computer use.

Logo has had an important part to play in shaping the view that computers are for thinking. This structured and easy-to-use language has made it possible to define in a *concrete way* many of the thinking processes that children engage in during the course of solving problems.

Despite Logo's significant impact on educational computing, there has been a lot of confusion (misunderstanding even) about how to use the language to promote the development of effective thinking and learning. This chapter illustrates some uses of Logo for developing students' thinking skills.

EDUCATIONAL AND PSYCHOLOGICAL FOUNDATIONS

Piaget's Influence

Seymour Papert, the inventor of Logo, adopted many aspects of Piaget's cognitive-developmental model (Piaget, 1971). This position states that the child's basic mental structure is the result of *interaction between internal processes and the environment*. According to Piaget, the child's intellectual development proceeds systematically through a progression of developmental stages that become more complex and integrated as the child matures. To facilitate this development, the child needs an opportunity to explore. Instruction occurs when children *initiate* an action in their environment rather than simply respond to imposed actions by teachers.

Papert's Beliefs

Like Piaget, Papert (1980) makes the point that children are "developers of their own intellectual structures." He believes that children need to interact with the environment around them to obtain the information and experiences that will help them to progress in their intellectual development. Contrary to Piaget's views, Papert proposes that it may be possible to accelerate childrens' intellectual growth through providing the right environmental conditions.

Papert suggests that a major cause of slow intellectual development in children may be the "relative poverty of the culture in those materials that would make the concept simple and concrete" (Papert, 1980, p. 7). In Papert's view, computers can be used to help accelerate the learning process. He believes that Logo can assist the child by providing an environment that encourages free exploration and contains the materials needed to become an effective *builder*.

Logo Theory and Research

Papert's views of Logo and the learning process are largely related to a "constructivist" perspective. This position is founded on the belief that children learn in their own time through their own experiences rather than from following a structured curriculum. The primary educational goal of a constructivist perspective is the creation of an adaptive culture/curriculum that encourages the *articulation and self-evaluation of thought* (Silvern & Williamson, 1986). This is reflected in Papert's comments on the teacher's role in "supporting children as they build their own intellectual structures with materials drawn from the surrounding culture" (Papert, 1980, p.32).

Not surprisingly, there has been a lot of debate about the purpose of Logo and how it should be taught (Papert, 1987). The research evidence is not clear-cut and seems to suggest that the learning outcomes from Logo depend as much on the type of teacher intervention provided as they do upon programming opportunities (Au, Horton, & Ryba, 1987). The following are a few examples of the types of research that have been undertaken with Logo.

Metacognitive and Cognitive Development

First-Grade Students—Students who received Logo instruction did better than those who were given CAI on tests of classification, serialization, and metacognition (Clements, 1986).

Junior High Students—Logo students outperformed control group students on tests of exploration, analysis and planning, and prediction (Horton & Ryba, 1986).

Elementary Students—Pea and Kurland (1984) found that Logo did not help students develop their planning skills.

Social-Emotional Development

Young Offenders—The use of computers has been shown to help these students develop a sense of personal control and self-discipline (Nolan & Ryba, 1987).

Severely Physically Disabled—The application of Logo as a learning tool for helping these students to develop social and communication skills has been demonstrated by Sylvia Weir (1987).

Hyperactive Children—The use of Logo as a socializing agent has been described by Michayluk and Saklofske (1988).

The success of Logo largely depends upon how it is used. It is especially important to consider:

- the type of teacher intervention provided.
- the sort of learning tasks provided.
- the social context of learning with Logo.

With these factors in mind, the remainder of this chapter explains how to create effective Logo learning environments.

DESIGNING THE LOGO LEARNING ENVIRONMENT

The Teacher's Role

The teacher's role is to create and support learning opportunities through:

1. Talking with students
2. Asking questions that encourage reflective thinking
3. Facilitating discussions for the sharing of ideas

Such points of consideration relate very closely to how teachers fulfill the role of anthropologist as described by Papert (1980). In this role, the teacher needs to understand how cultural materials are relevant to intellectual development. This understanding comes from watching how children talk with one another, how they respond to teaching materials and methods, and how they interact with the computer. You are then more able to create an environment that supports childrens' intellectual development.

Logo lends itself to discovery learning methods. These enable students to investigate ideas for themselves rather than being "taught" programming operations in any formal sense. Such an approach requires that teachers change from their traditional role as providers of information to facilitators of learning. The teacher is not expected to know the answers to all questions posed by the students, but rather to know the process of investigation—how to go about finding the answers. Appropriate questioning skills are vital (Lockard, Abrams, & Many, 1987).

Students need to be encouraged to discuss with each other the reasons and ways they obtained certain solutions. These discussions can be carried out both in small groups and by the class as a whole. The focus of these discussions should be on the processes by which they arrived at their solutions, rather than on the programming outcomes. For instance, at the beginning of a session, the teacher can provide some interesting problems. Students can work on these problems and then share their solution strategies.

As Papert pointed out, "teaching without a curriculum" does not mean spontaneous, free-form classrooms or simply leaving the child alone (Papert, 1980, p. 31). It means providing the right kinds of support to help ensure that the appropriate learning opportunities occur. This requires materials and methods that prompt students to engage in certain thinking processes. For example, activities and suggestions are needed that encourage students to do some of their own experimenting, predicting, planning, and self-evaluation.

Teacher Questioning

Teacher questioning is the key to development of effective thinking with Logo. Instead of providing answers to students, you should try to encourage your students to think about their own thinking by asking the right kind of questions. For instance, when a student has problems, you should ask questions that give control back to the student:

- "Is that what you wanted to do?"
- "What do you think you should do now?"
- "Did it turn out the way you planned ?"
- "How are you going to fix it?"

Avoid giving answers to students except when they are really stuck. Instead, encourage students to reflect on their own thinking. Questions can be asked that help promote the development of specific thinking skills:

Prediction: "Draw what you guess will happen."

Experimentation: "Play around with different numbers for the REPEAT command."

Planning: "Make a plan first then try it out on the computer."

Analysis and Evaluation: "What didn't work in your plan and how are you going to change it?"

You can help students to foster their abstract thinking. For instance, when students are trying to predict the movements of the turtle or plan a certain drawing, get them to walk out the movements of the turtle, either individually or in a group, or to draw the turtle's path on a piece of paper. Later on, encourage students to think through problems mentally, rather than physically acting them out. "Blackboard challenges" can be a good way of promoting discussions about thinking and learning strategies. Students can work individually or in teams to test solutions to the challenges on the computer.

A TYPICAL LESSON

The following lesson shows the type of teacher intervention that can promote learning with Logo.

1. For the first few minutes of the session, the teacher introduced the key concepts of the worksheets (e.g., defining procedures). Students were first asked to explore what happened when they typed SQUARE, for example. The teacher helped the students' exploration by asking questions such as, "What does the turtle do when you type SQUARE?" Based on the turtle's response, "I DO NOT KNOW HOW TO SQUARE," students were then guided in how to teach the turtle a new word. Predictions were made on the outcome of these new words (e.g., "Predict what commands need to be in a procedure to draw a circle"). Further explorations were encouraged (e.g., "How about teaching the turtle a new word to draw a triangle?"). Once students were familiar with the key concepts of the lesson, they were able to progress with their individual work.

2. For the next hour, students were asked to work individually, alternating between 15 minutes on the computer and 15 minutes off. While off the computer they followed the general problem solving model by spending their time predicting and planning their worksheet activities, either individually or in groups. Their plans and predictions were then tried out on the computer. If their plans did not work, they were encouraged to ask themselves where the bugs were, to revise their plans, and then to try them out on the computer again. During this time the teacher was there to facilitate and monitor the progress of the students' learning by using questioning techniques. The questions and suggestions impelled the students to develop their thinking skills and problem solving processes. Examples of teacher comments during this process are: "Estimate how many degrees the turtle needs to turn by walking it out for yourself."; "Experiment with those commands on the computer."; "Think through your steps carefully when you are planning."; "Think it ahead before you actually try it out."; "What do these commands actually do?"; "Check through your plan carefully."

3. At the end of the session, the teacher provided opportunities for students to discuss and share their ideas and any problems that had arisen during the session. Such problems formed the basis for class discussions on how they could be solved. Students were also encouraged to focus specifically on the processes they used to solve problems (e.g., "I predicted the commands by walking them out first. This way I found out where I had gone wrong in my planning."). The teacher also provided opportunities for programming challenges that specifically related to the session's main concepts (e.g., "Let's see who can predict the outcome of this procedure," "Draw your predictions on the blackboard so that we can all compare the outcomes," "Now let's discuss how we made these predictions," "Where have some of us gone wrong?," etc.). These types of challenges were used to actively encourage students in shifting from a concrete method (walking out or drawing the turtle's path) to an abstract method (thinking through in their own minds) of problem solving. (Au, Horton, & Ryba, 1987, p. 14)

TEACHING STRATEGIES

This section describes some specific activities and teaching approaches that can be used to develop skills in exploration, analysis and planning, and self-monitoring. Many of the suggestions presented here are from *Assessing Learning With LOGO* by Pat Nolan and Ken Ryba (1986).

Exploration

Exploratory activities are a good starting place to help children learn to articulate their ideas and problems. Through the use of turtle graphics, students have a realistic setting for observing and describing, predicting and explaining, and comparing and contrasting. The following activities can be used to encourage exploration:

1. *Present students with prediction tasks.* "Draw a picture to show what you think this procedure (set of commands) will tell the turtle to do." Worksheets like the example presented here can be used for this activity.

2. *Type the commands into the computer to see what happens.* "Compare your 'guess' drawing with the drawing that the turtle made. Were they the same or different? If they were different, can you explain why?"

3. *Ask students to work in pairs or small groups to do the following:*

   a. Make a pattern that uses the REPEAT command.
   b. Ask other students or groups to predict the outcome of the REPEAT command.
   c. Discuss any false predictions, diagnose problems, and propose alternative solutions.

4. *Provide students with a sample program that contains a variety of commands and values.* Ask them to experiment by adding and/or deleting commands and by changing command values. Ask them to observe and record the effects of changes they make. Because programming with Logo is structured and purposeful, students should be encouraged to keep their own personal logs for tracking the progress they make.

Remember that the aim of these exercises is to increase students' awareness of the kinds of exploration that can be undertaken. It is good to start with a structured activity at the beginning, and then provide opportunities later on for students to write and explore their own procedures. Students will vary in their approaches to exploration. Some will explore the full range of possibilities from the outset while others will need guidance to see the alternatives that are available. The activities presented here can cater to such individual differences and provide a basis for discussing the exploration process. (See *Exploring With Logo Procedures* worksheet on next page.)

Analysis and Planning

Students working with Logo often engage in informal planning. They spontaneously work out problems in their heads and don't prepare any written plans or notes about the methods they are using. While this informal analysis and planning works well for some students, it is not good for everyone. Many learners need guidance and direction to learn methods of planning that are effective for them. For example, some students work best in a situation where they have detailed and orderly written plans. Many will use a few notes to outline their ideas, but do little formal planning. Others will plan in a spontaneous way by following the "insights" that develop in their minds. Any one of these methods can be effective, but not for all students.

Our view is that the general methods for planning and problem solving need to be taught. The teacher's role is to help students become aware of which approaches to analysis and planning are most effective for them. Teaching this self-awareness requires a thorough assessment to determine how and to what extent students are reflecting on planning. There are three main steps in this assessment:

1. Observe the particular kinds of analysis and planning approaches that a student uses.

2. Assess the effectiveness of these approaches in relation to the student's style of learning.

3. Intervene when necessary to help students learn alternate methods of planning that might be more effective for them.

Here are some activities that can be used to promote students' skills in analysis and planning:

1. Do a project with the class that illustrates the four main planning steps. Work together with students to make a drawing of the proposed project, and then work out a plan to draw the project. Ask students to carry out the plan on their computers. Then ask them to look back—checking and making changes. Discuss the results with reference to the planning steps.

Name: _____

Date: _____

Exploring With Logo Procedures

1. Type in the following procedure.

```
TO TRI
>REPEAT 3 [ FD 50 RT 120 ]
>END
```

Now experiment to see what patterns you can make with TRI. Try this one to get started:

```
TRI
RT 90
TRI
RT 90
TRI
RT 90
TRI
RT 90
```

Draw a picture to show what the Turtle made.

What happens if you change RT 90 to RT 45?

What happens if you change RT 90 to LT 90?

Explore what happens when you use TRI with other commands.

Make a picture of any design you discovered when playing around with TRI.

Reprinted from *Assessing Learning with Logo* by Pat Nolan and Ken Ryba. Eugene, OR: ISTE, pp. 68-70.

It will be helpful to prepare an overhead/ handout that shows the four main steps of analysis and planning (presented in Chapter 3):

Step 1: Understand the Problem. Make a drawing of the proposed project. Describe the main parts that are needed and how these might be put together.

Step 2: Make a plan. Write a procedure that you think will tell the computer how to make the project.

Step 3: Carry Out the Plan. Type the commands into the computer and then draw a picture of what the turtle did.

Step 4: Look Back. Decide if the turtle did what you wanted it to. If it didn't, go back and make changes.

2. Have a class discussion about the steps involved in analysis and planning. Explain that having a plan is more than just following a fixed scheme; it means being systematic in making and changing plans to suit a particular situation. Here, we make a plan, analyze it as we are working on the problem, and make changes that we think are needed to help improve the work.

Ask students to help prepare a planning checklist for the class. Ask them to describe which methods they find helpful. For example:

- "Take time to think through a problem."
- "Be systematic in working on problems."
- "Work out a general plan of attack."
- "Evaluate plans and make changes as needed."
- "Try alternative ways of approaching the problem."

Encourage students to talk about methods and problems encountered in planning their work. This verbal rehearsal is a good way for them to become aware of their planning skills.

3. Ask students to do a project of their own following the four steps of analysis and planning. Have them keep a written record of the four main steps they followed.

Understand the Problem: "Make a drawing of your project here. Explain in your own words what the main parts of the drawing are and how these can be put together."

Make a Plan: "Write your procedure here."

Carry Out the Plan: "Type the commands into the computer."

Look Back: "Did you teach the turtle to draw what you wanted the first time? What changes did you need to make? Did you stick to the same plan from the start to the finish?"

(See *Checking Your Analysis and Planning Skills* worksheet on the next page.)

Self-Monitoring (Debugging)

The idea of being *free* to make mistakes and explore alternate solutions to problems runs contrary to many traditional views of schooling. As teachers, we can help by providing the conditions that students need to engage in debugging as a natural and enjoyable process. Sensitivity and care should be used to ensure that students gain an awareness of debugging as a learning tool. We are not only talking about programming errors, but also about the different ways in which a turtle behaves. The turtle may behave in ways that are either intended or unanticipated by the student. In any event, the student's task is to understand the turtle's behavior and to fix or modify it as needed to produce a desired effect.

Self-monitoring is a natural part of learning with Logo and does not really need to be prompted through separate programming activities. There are, however, some approaches that teachers can use to focus students' attention on these checking and regulating activities.

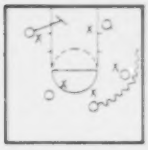
1. Have students work in pairs to prepare a debugging checklist. This should include helpful hints that others could use as a guide for debugging programs. For example:

- "Check each command line by line."
- "Draw a picture or walk through each of the turtle's moves."
- "Underline each suspected bug."

As a class activity, prepare a master checklist using the helpful hints that each pair of students identified. This will generate a lot of discussion on types of bugs and effective ways of locating and fixing bugs. It goes without saying that bugs are an interesting and normal part of learning with Logo.

Name: _____

Date: _____



Checking Your Analysis and Planning Skills

Defining Procedures

1. Think about how you would make this design using a procedure.

A. **Make a plan.** Write the commands here that tell the computer what to do.

B. **Carry out the plan.** Type the commands into the computer.
Draw a picture of what the Turtle did.

C. **Look back.** Compare the drawing above with what the Turtle made. If they are not the same, go back and find the bugs and make the changes.

What bugs did you find? Explain how you fixed these.

Think back on how you made this design.
What step did you do first?

What steps did you do next?

What step did you do last?

Reprinted from *Assessing Learning with Logo* by Pat Nolan and Ken Ryba. Eugene, OR: ISTE, pp. 77-79.

2. Do a class project to illustrate the ways in which bugs can be used to promote thinking. Explain that bugs are not necessarily right or wrong, good or bad. There are times when bugs provide a source of ideas for inventing something new. Finding and fixing bugs often lead us to new ways of thinking about a problem. For example:

"Have a look at this procedure. It has some bugs that keep it from working exactly as we want."

Ask students to think about some ways they could use the procedure as it is to invent something new. Encourage them to think about:

- new ideas that come to mind.
- ways of improving the program.
- ways of changing the program.

Have students work individually or in teams to change the procedure any way they like. Ask them to keep a record of the changes they make.

Ask students to present their new inventions to the class and describe the changes they made.

3. Have a class discussion about the use of procedures in other areas of life. Describe some everyday activities in which people use procedures. For example, following a recipe, reading a set of instructions, and giving someone directions are all procedures of a similar kind. They contain an orderly set of instructions that help people think in a systematic way. Ask students to think of situations in their own lives where they follow or make procedures of their own.

   Ask students to do an exercise that helps them draw a connection between procedures in real life and procedures for the turtle. For example, you might have them do the following activity and answer the corresponding questions:

Think about the steps involved in doing each of the following things:

- Turning on the computer and loading a program from disk.
- Doing addition on a calculator.
- Drawing a square with paper, pencil, and a ruler.

1. Write a procedure which contains a set of instructions for doing one of the above. Be sure to write down all the steps in the order they should be done. Use as many steps as you need to.

```
TO
>
>
>
END
```

2. Ask another student to check and debug your procedure. Keep a record of any changes made.

3. Write down any changes made here.

4. Did you agree with the changes they made? If not, explain why.

5. Explain how fixing real-life procedures is like fixing procedures for the turtle.

6. Explain how fixing real-life procedures is unlike fixing procedures for the turtle.

Have a class discussion about the procedure-writing exercise. Ask students to talk about their procedures and any bugs that they found. Use these examples to illustrate how bugs can occur in real-life procedures just the same way as they do in Logo procedures. Encourage students to think of bugs as a natural and enjoyable part of the learning process.

(See *Checking Your Debugging Skills* and *Logo Environment Checklist* at the end of this chapter.)

Name: _____

Date: _____

Checking Your Debugging Skills

Defining Procedures

1. This procedure is supposed to make an octagon but it doesn't work right. See if you can find the bugs.

```
?TO OCTAGON
>REPEAT 7
>FD 30 RT 45
>END
```

How many bugs did you find?

How did you figure out what the bugs were?

List the main steps you follow when debugging a procedure.
What is the first thing you do?

What things do you do next?

What is the last thing you do?

2. This procedure is supposed to make a house. Type in the commands to see what it does.

```
?TO HOUSE
>REPEAT 4 [ FD 50 RT 90 ]
>FD 50
>REPEAT 3 [ FD 40 RT 120 ]
>END
```

Draw a picture of what the Turtle made here.

Reprinted from *Assessing Learning with Logo* by Pat Nolan and Ken Ryba. Eugene, OR: ISTE, pp. 80-82

LOGO ENVIRONMENT CHECKLIST

Reprinted from "Logo, Teacher Intervention and the Development of Thinking Skills" by Wing Kee Au, Jane Horton, and Ken Ryba in *The Computing Teacher*, November 1987, p. 15.

Logo Worksheets

1. Do the worksheets provide a logical sequence of programming contents, from the simple to the complex?

2. Do the activities encourage learners to experiment with variations of the same problem (e.g., make different shapes with the REPEAT statement, changing the values)?

3. Do the activities encourage students to plan their solutions systematically (step-by-step analysis of what they did and how they did it)?

4. Do the activities encourage students to analyze/check (test out) their solutions (planning) before going to the computer (e.g., walking it out, drawing it out or thinking it out)?

5. Do the worksheets encourage students to think procedurally by working out problems on a step-by-step basis (following a problem solving model)?

6. Do the worksheets encourage students to use a systematic method for locating and fixing mistakes before they change their plans (e.g., line-by-line analysis)?

7. Do the worksheets encourage students to break down complex problems into smaller and simpler subproblems (e.g., commands in a procedure, subprocedure and superprocedure, structure diagram)?

8. Does each worksheet help the students analyse the different strategies for solving the same problem (e.g., combining commands using the REPEAT statement)?

Teacher Questioning

9. Do you provide individual consultation for the students to help guide them with their problem solving?

10. Do you provide training/instruction while at the same time encouraging students to think for themselves (e.g., trying out different inputs to a REPEAT statement)?

11. Do you encourage students to break down complicated problems into smaller and simpler problems (e.g., commands in a procedure, superprocedures and subprocedures, structure diagrams)?

12. Do you reinforce students for creating new ideas and programs/products (e.g., verbal praise, class recognition)?

13. Do you provide meaningful positive reinforcement to students who engage in the use of problem solving processes (e.g., verbal praise, class recognition)?

14. Do you ask students to explain in their own words how they figured out their solutions to problems?

15. Do you encourage students to create their own original ideas by looking into their own minds, observing the surroundings, and extending other people's ideas?

16. Do you encourage students to apply the general problem solving processes to non-Logo situations (e.g., writing a procedure for fixing a peanut butter and jelly sandwich, planning a trip, or solving a personal problem)?

17. Do you encourage students to be flexible thinkers (e.g., to write different procedures to draw the same shape)?

18. Do you ask questions which clarify the problem (e.g., What do you want the Turtle to do?)?

19. Do you give time to students to answer the question (e.g., count to five before commenting)?

20. Do you ask follow-up questions (e.g., Why do you think the Turtle did that?)?

21. Do you encourage students to summarize the problems in their own words as part of their answers (stating the problem for one's self often leads to a solution)?

22. Do you help students become more fluent thinkers (e.g., How many ways can you think of doing this? How many different shapes can you draw using this REPEAT command?)?

23. Do you encourage students to synthesize subsolutions into a big solution (providing linking steps to join different subprocedures into a superprocedure)?

24. Do you use questions to encourage students to reflect on their own thinking (ask questions that lead to solutions without giving the answer)?

Socially Interactive and Reflective Environment

25. Do you keep your hands off the students' keyboards?

26. Do you encourage students to talk about what they did and why and how they did it?

27. Do you provide opportunities for learners to work on problems as a group, sharing ways of arriving at their solutions?

28. Do you have class activities which encourage individual students to explain their own thinking to other students?

29. Do you provide adequate time for students to plan and predict off the computer (e.g., walking out commands, drawing out the commands, etc.)?

30. Do you provide adequate time for students to test their solutions on the computer?

Chapter 6 ADVENTURE GAMES AND THINKING SKILLS

BY JAN HORREX AND KEN RYBA

Adventure games are well suited to developing thinking skills in the ways outlined in this book. The reason for this is that most games provide a definite *social context* within which problem solving takes place. By taking on the role of a character portrayed in the microworld, students have a chance to engage in various types of personal problem solving. The process of working with other students who are also participating in the game leads to natural social interaction and shared strategies for dealing with problems encountered.

WHAT ARE ADVENTURE GAMES?

Adventure games are fantasy worlds or computer simulations of real worlds that offer students the opportunity to explore and test a variety of problem solving strategies in their efforts to master the game. Usually adventure games involve achieving a particular goal, such as collecting treasures or tools, finding one's way out of a tunnel or maze, trapping a criminal, or preventing a catastrophe (Dailhou, 1985). To achieve the goal invariably leads the learner into a complex problem solving situation with short-, medium-, and long-term problems that all need to be successfully solved if the game is to be mastered. As Clayson (1982) has pointed out, it is not the complexity of the program that is important, but the player's ability to explore alternate strategies until the most suitable one is found.

Although there is a vast array of different types of adventure games in today's marketplace, they usually have four main components in common:

1. a setting or scenario in which the game begins;
2. characters who live within the game;
3. objectives, tasks, or goals to be accomplished; and
4. the opportunity to interact with the game through the maneuvering of the characters and objects within the microworld.

Two well known examples of adventure games are:

1. *Dinosaur Discovery* (Jacaranda). This is a microworld where students become explorers and scientists. The aim is to hunt for a treasure (a dinosaur egg) in a strange land. In the process, students are confronted with hazards (jungle, swamp, quicksand) and problem solving activities (crosswords, mazes).

2. *Where in the World is Carmen San Diego?* (Broderbund). In this game, the player becomes a detective, tracking down a criminal by following geographical clues. The player receives clues at various locations about the identity of the person who committed the crime. The player is required to follow clues correctly in order to solve the crime and apprehend the criminal. Several versions of the game are available.

There are many other adventure games available commercially. For a review of specific programs suitable for the development of higher order thinking skills see Vockell and van Deusen (1989).

While it has been emphasized that adventure games are inherently suited to the development of problem solving strategies, it must also be emphasized that they are fun! By their very nature, computer games motivate, stimulate, increase attention, and encourage active participation in the learning process.

WHY USE ADVENTURE GAMES IN THE CLASSROOM?

To suggest teachers use adventure games as learning tools may seem contrary to what has traditionally constituted'"suitable" learning material, and yet they are immensely valuable for several important reasons. First, recent research evidence would suggest adventure games are an ideal context within which to develop students' thinking skills, including reflecting on what needs to be done to solve problems, developing a plan, executing the plan, and evaluating their progress toward reaching a goal. Because adventure games provide immediate feedback, students can see the consequences of their actions. This gives them the chance to modify their plan of action, test it out, and evaluate it yet again—and this can all happen without depending upon a teacher. By their very nature, adventure games encourage students to take calculated risks without fear of failure. Students soon come to realize that it is okay to make mistakes and that valuable learning can arise from fixing errors.

Second, adventure games provide the structure for creating a cooperative learning environment (as described in Chapter 4). Within this environment students are provided with opportunities to:

- talk about their thinking processes.
- trigger one another to engage in discussion.
- model thinking skills for one another.
- reflect on the effectiveness of strategies employed by others.
- teach each other relevant concepts or information.
- assist one another in diagnosing and analyzing problems.
- keep each other on task.
- share in the pleasure of mastering the game.

Of all simulations now available, adventure games are the most ego involving—the player takes on the role of a character portrayed in the program. Through learning to work successfully with others, students can develop valuable social skills that will hopefully be generalized to other learning situations. For example, students must learn who has responsibility for particular aspects of the game. They must also learn how to resolve any group conflicts that may arise.

Third, adventure games can help to develop and reinforce a range of other valuable academic skills such as:

1. **Reading skills.** In many instances students will need to decode and comprehend instructions, directions, symbols, and new vocabulary on and off the screen. Students may also be involved in rereading any notes taken during the game, locating the main points, and cross-checking tables of information.

2. **Recording skills.** To make informed decisions when playing adventure games may require players to chart information on a grid, list details, make notes, graph data, or draw a map to locate places, objects, or players.

3. **Study skills.** Players may need to locate additional information, ascertain the meaning of new terminology, make brief notes about the main points, or memorize information.

4. **Mathematical skills.** Beyond needing to add, subtract, multiply, and divide when playing an adventure game, students may often need to estimate distances and time, follow compass directions, draw plans or maps to scale, and show a basic understanding of geometry.

5. **Keyboard skills.** If some students are uncertain or lack confidence when using a computer keyboard, the desire to play a computer game will almost certainly help them overcome their fears. It will also assist in familiarizing them with the location and function of different keys.

6. **Discussion skills.** The need to work out suitable strategies in order to solve the problems within a game is likely to encourage even the shyest student to share information and ideas. With time and practice in cooperative learning situations, students will hopefully learn to be succinct, logical, and clear when putting forward ideas, while simultaneously developing good listening skills.

With the range of games now available, it is possible to choose one that relates to the content areas of the curriculum. For instance, *Where In The World Is Carmen Sandiego?* crosses the subject areas of social studies, geography, and English. Fantasy adventures such as *Gold Dust Island* (Jacaranda) that do not fit within a specific subject area can be used to develop a range of skills in social collaboration, verbal and written presentations, use of reference materials, and vocabulary usage.

Adventure games provide many opportunities for off-computer work (e.g., mapping, discussing, studying logs). These situations enable students to work *interdependently* in noncomputer contexts. Whole class activities can be set up around the theme of an adventure program. These activities could involve library research, group study, class presentations, production of posters and illustrations, and the use of other computer applications. For instance, database or spreadsheet programs might be employed to store and process information about the adventures. It is essential, however, to see that the adventure program and related activities are well integrated into the curriculum.

THE TEACHER'S ROLE

In recognizing the potential benefits to be gained from using adventure games as learning tools, it must also be emphasized that this potential is almost certainly dependent upon the teacher (see Chapter 2). Research evidence indicates that the way teachers incorporate computers into the learning environment and the way they approach the task of teaching problem solving skills could be largely responsible for whether or not adven-

ture games enhance the learning process. Thus, it is the teacher rather than the medium per se that determines the usefulness of adventure games.

Following is a brief description of the main aspects of the teacher's role.

1. **Planner.** As a planner, the teacher must ensure the software fits with the teaching aims. In addition to selecting suitable software and becoming familiar with all facets of the game, you must plan the physical environment to ensure all students can see the screen and use the keyboard. It's also important to ensure that each group can work problems through to a satisfactory conclusion, and that there is time for postgame class/group discussion.

   In planning a cooperative learning situation, groups must be carefully organized to take account of individual abilities, gender, cultural background, and personal choices. There may also be the need to teach certain students the necessary social skills required for them to effectively participate within the group, especially to ensure that positive interdependence occurs (Male, 1988).

   Planning must include evaluation of the learning environment, the teaching process, the students' use of appropriate problem solving strategies, and their enjoyment of the game. You can achieve this through observation and informal responses by students to questions like:

   - "Did you have any difficulties working in your study group?"
   - "What steps did you use to solve the problem of...?"
   - "Did you find the group debriefing sessions useful?"

   Similar questions could be used on a questionnaire to gauge individual students' understanding and use of problem solving strategies. Evaluation may also include using a different adventure game or noncomputer problem solving situation to assess the degree to which students are able to independently employ problem solving strategies (see Chapter 3).

2. **Facilitator.** The teacher should familiarize students with the game environment and teach them prerequisite skills that will assist students in playing the game (e.g., how to keep track of one's moves by using a grid or drawing a map). This preparation will help ensure that students focus on problem solving instead of incidental factors.

3. **Manager.** In this role, the teacher needs to ensure that all students are actively participating in the game. You can provide help when necessary to promote metacognitive awareness and assist students to develop self-regulation strategies. You should also be aware of when to fade support in order to encourage students to become "teacher-independent thinkers."

4. **Guide.** As a guide, the teacher should encourage students to effectively employ problem solving strategies. You can question them about how they intend to go about a particular task and what alternate strategies they could use. As a followup, you can ask if the approach they selected was effective in solving the problem. You can use "think-aloud" procedures to show them particular strategies. You can also encourage students to realize that talking about their thinking can be a valuable problem solving strategy.

5. **Model.** In modeling particular problem solving strategies, the teacher is able to demonstrate other important qualities necessary for successful learning in a cooperative situation. For instance, you can show them how it might be necessary to change approaches depending on the problem. This is particularly important as research has revealed that girls tend to only adopt one approach and maintain it throughout a game (Mandinach & Corno, 1985, cited by Mandinach & Linn, 1986). You can also show sensitivity for the feelings and needs of other group members, while providing encouragement and support. Last, but not least, show a sense of humor when all doesn't quite go according to plan!

6. **Participant.** As a participant, the teacher is able to develop a special rapport with the students in the group. This role allows you to observe students from a different perspective and also allows immediate feedback and timely intervention when and where necessary. By actively participating, you can share with students the excitement and thrill of mastering the game.

While these aspects of the teacher's role can be demanding, the rewards to be gained by both student and teacher make it all worthwhile.

TEACHER INTERVENTION GUIDELINES

During the session, encourage students to:

1. Exchange and share ideas.
2. Keep a map or record of turns.
3. Talk about their problems and how to solve them.
4. Think of alternate ways to solve problems.
5. Work out the problem for themselves.
6. Reflect on their own thinking.
7. Write down instructions so they have a record of what to do.
8. Scan for hints and clues.
9. Think for themselves.

Remember to do the following:

1. Provide individual consultation with students.
2. Ask questions that clarify the problem.
3. Ask students to explain in their own words how they solved a problem.
4. Give students time to answer questions.
5. Ask followup questions.
6. Keep your hands off the students keyboards.
7. Plan group activities in which students have to explain their thinking to other students.
8. Have discussions off the computer at the beginning and end of each session.

GOLD DUST ISLAND—A CASE STUDY

Jacaranda Software (1984)
Level: 10 years and up
Program length: 20 to 45 minutes
Number of Players: 2 to 5 players

As a resource teacher in a high school, I decided to use *Gold Dust Island* as a cooperative learning task with students who had learning difficulties. I tried the program with six heterogeneous groups of students. Each group contained a mix of students with learning difficulties and students with regular achievement skills. The main aim was to enable students to work successfully and gain pleasure from learning together in a cooperative situation. Social skills (e.g., sharing an idea, working collaboratively) were directly taught as part of the game problem solving procedure. I thought that this adventure would be suitable for the mixed groups because it did not make any assumptions about their knowledge of subject areas. Each student would thus have a similar chance of succeeding.

Description of the Game

Gold Dust Island lends itself to a cooperative problem solving approach. It requires little background knowledge to play the game or operate the keyboard, requires minimal reading skills, and contains no culture or gender bias. It is suitable for mixed groups of students in terms of age, ability, gender, and race.

The game begins with a group of people who are marooned on an island after being shipwrecked. Each finds a set of tools on the beach that are useful for boat building or gold mining. As the game progresses, players can fetch water, fill up the wells, dig for gold, build the boat, or trade tools, gold, water, and boat building points. The aim of the game is for the group to leave the island safely before a cyclone arrives, while at the same time having something (gold) to show for their time spent on the island. To achieve this aim involves solving numerous problems. For instance, one of the on-going problems is ensuring that everyone has enough water, for each time a player has a turn, they use up a day's supply of water. If a player runs out of water they die and their tools and gold go with them!

Teacher and Student Responses to Gold Dust Island

I introduced students to the scenario and then left them to explore the setting, the logistics of moving, and the usefulness of their tools. Afterwards, as a group member, I was then able to trigger discussion with questions such as "What if some players concentrated on building the boat and digging for gold, while the rest of the group fetches water?" These types of questions led students to realize the potential for cooperating and planning. Questions also proved useful in prompting students to internalize problem solving strategies, for example:

Teacher: *"What do you need to do now?"*

Student: *"Get some more water."*

Teacher: *"How many paces do you think you'll need to move to get into the water area?"*

Student: *"About 30."*

Teacher: *"If you don't move far enough, will you have enough water left for another turn?"*

In addition to questioning, I also employed "think-aloud" procedures to help students see what problem solving skills I used. For instance, I made statements such as "I only have four days water supply left, so I can only spend one more turn helping build the boat before I need to fetch more water because it takes me three days supply to get to the water area from here." In turn, students also verbalized their thoughts, which helped them to reflect on their thinking.

As the game progressed, students gradually perceived the benefits of cooperating, planning, and sharing resources. Interestingly, when some of these student groups played another game of *Gold Dust Island*, they entered into active, purposeful discussion and planning right at the outset of the game. Their motivation, interest, and attention appeared even greater during the second game. Their enthusiasm was also reflected in their pleas to be allowed further games of *Gold Dust Island*. Also worth noting is the support and encouragement students offered one another and the sense of cohesiveness among the group members. No one person dominated and all actively participated.

After completing the game, I held a class discussion on problem solving, cooperation, and other matters relating to the game. The game itself was also a catalyst for other classroom activities such as writing essays, examining the importance of fresh water for survival, and creating art work.

Gold Dust Island provided an excellent cooperative learning task and a valuable focus for discussion. It was challenging, interesting, and most satisfying, especially when as a group we were able to build our boat and therefore survive the cyclone.

WHERE IN THE WORLD IS CARMEN SANDIEGO?—A CASE STUDY

Besides the obvious educational values of using this program (i.e., locating cities and countries, using reference materials, collecting information, and developing problem solving skills), Nancy Fortman (1989) saw a great opportunity to teach database usage to her sixth graders:

> Initially students were grouped and given several class sessions to play *Carmen*. They were asked to record on a word processor all of the clues that they had encountered while playing the game. After several class sessions, the list grew to more than 1,000. We printed out a hard copy of the clues and began arranging them in some order. After analyzing the information in the clues and brainstorming, the clues were organized into 13 categories: city, country, currency, flag, monuments, bodies of water, mountains, deserts, language, chief products, animals, government, and vocabulary.
>
> There are 30 countries used in the *Carmen* program. Students chose a country (some working in pairs) to collect the information needed for each category. They used almanacs, atlases, and encyclopedias available in the school library. Using *AppleWorks*, a database file was created listing the 13 categories. Each student typed in the information on the country they had researched. Copies of the data disk were made and students were taught how to use the *AppleWorks* database program. Four class sessions were spent on learning and using the basic commands to retrieve information from the database.
>
> Now the test—just how much could the database help to solve cases with *Carmen*? Students played the game for several class sessions. They wholeheartedly agreed that the database was a great timesaver. They were also able to suggest ways of improving the information they had stored.
>
> This popular program allowed us to teach lessons in research skills and the use of a word processor and database. The students' effort and time produced a valuable database that can be shared with the entire school. (Fortman, 1989, p. 12)

CRITERIA FOR SELECTING ADVENTURE GAMES

While there is a vast array of computer games from which to select, not all will be suitable for classroom use. The following checklist presents some important points to consider about the educational value of adventure game software.

1. *Does the adventure game package:*

   (a) promote your learning objectives?
   (b) encourage collaborative learning?
   (c) contain stereotypes or bias (either cultural or gender related)?
   (d) include appropriately detailed manuals?
   (e) provide suitable feedback?
   (f) contain appropriate graphics and sound (i.e., they do not distract from the learning process)?

2. *Is the program:*

   (a) user friendly?
   (b) likely to maintain students' interest?
   (c) of a suitable length?
   (d) varied in its level of complexity?

3. Is the reading level suitable for your students?

4. Is the type of input suitable (i.e., single keystroke, whole word, phrase of computer sentence)?

These last two factors are important. If students are forced to concentrate on reading or the mechanics of executing their decisions, they may in fact be unable to focus their attention on developing valuable problem solving skills.

SUMMARY

There appear to be several benefits in using adventure games to teach problem solving skills to groups of students. First, the introduction initiates a change in the teacher's role. By focusing on adventure games as a medium through which to teach, the teacher is able to facilitate learning. S/he does this by working alongside students, discussing the importance of strategies, modeling these strategies, and using questions to prompt students to verbalize their thinking. Second, adventure games lend themselves to being used in cooperative learning situations that encourage students to discuss, explain, justify and model their ideas to one another, thus increasing the effectiveness of the learning process. Third, adventure games are exciting, challenging, motivating, and highly interactive. These factors ensure that students' attention is constantly focused on the game, thereby increasing the likelihood that students will develop, practice, and transfer their problem solving skills.

Chapter 7 WORD PROCESSING AND THINKING SKILLS

Teachers using computers within their writing program reply enthusiastically when asked about the computer's effects. Responses usually focus on the way students are able to become more original in their thinking, more fluent and flexible in their composing and revising, and more motivated to write. From the comments teachers make, three main messages about writing with computers can be noted:

1. The physical aspects of writing are eased.
2. The social side of writing is encouraged.
3. Students are able to concentrate on the thinking and problem solving skills involved in writing.

APPROACHES TO WRITING

Problem solving in writing involves the need for planning and analysis, for checking and evaluation, and for exploration and creativity. Flower (1985) describes writing as a problem solving exercise and suggests a variety of strategies that can be used to overcome the problems writers face as they work to complete a piece of text. Flower ties these strategies into nine separate steps that start with exploring the problem, and end with editing and checking to ensure a clear, powerful, and logical text.

A different approach, enthusiastically advocated by Graves (1983), views writing as consisting of three main areas—prewriting, writing, and revising and editing. Publication is considered to be the final step in the writing process because it brings the completed work to an audience. Although these areas seem like stages in a linear sequence, a straight progression is not intended.

A basic tenet of this approach is that throughout the writing process, writers retain control of, and responsibility for, their writing.

Prewriting

The writer has responsibility for topic selection. Students discuss and explore ideas, plan outlines, evaluate proposals, and gradually form the intention to write.

Writing

Students put their ideas into written form. Ideas are changed from scattered notes or outlines into a sequential text.

Revising and Editing

Writers are responsible for clarifying their writing. Revising can occur at any stage as students monitor their work in the process of writing, or go back and check a finished text. Revision leads to amendment of ideas, expression, or organization. The editing of usage, punctuation, and spelling occurs in a similar fashion.

Publishing

The area of publication is one that involves many skills. Formatting written text and determining page layout contribute greatly to the quality of the final product. Integrating graphs, tables, and drawings with written text demands flair and imagination as well as a variety of other computer competencies. The boundary between the skills of composition and revision, and the skills of presentation is indistinct. In this chapter our main concern is with the thinking processes students engage in as they compose and revise their work.

SOME IMPORTANT ELEMENTS OF PROCESS WRITING

- Children want to write.
- Children should write about *their* experiences.
- The child must be the *owner* of the writing experience.
- Children should write every day.
- Spelling only becomes important when work is to be published.
- Students should talk about their writing.

Process writing ideally lends itself to the development of thinking skills and learning strategies. We see a problem solving approach adding to the process writing ideas proposed by Graves.

Prewriting is mainly concerned with the exploration of various ideas as students move toward selecting a topic and deciding on an audience. When a topic is given, the problem becomes one of working out how to approach it and deciding which hypotheses will be supported in the writing. Students will research topics, outline ideas, and plan and organize material before they begin to write. In writing text, students act on ideas from the prewriting stage and follow up on ideas that spring from revising and editing.

Use of computers supports the development of thinking skills through writing. Programs of various types have been designed to help writers learn about the writing process and to work through it more easily. In the sections that follow, we will describe some of the software available and show how students can use various programs to develop their own thinking and writing skills.

PREWRITING

Getting started is probably the most common problem writers face. For some students the problem is "What am I going to write about?" For others, the trouble is "What am I going to say?" or "Where do I start writing about this?" For many students, the problem is not that they can't think of a topic or think of a starting place, but rather that they haven't developed the strategies needed to move on from those initial questions.

In fact, research shows that planning takes up approximately half of a writer's time. Flowers and Hayes (1980) found that it is very important to have goals in the writing process. Deciding on goals, thinking up subgoals, and developing constraints (as well as changing and adding to these) are all activities that take up a large part of a writer's time. Planning strategies that teachers can introduce and discuss with their students include:

- deciding on subtopics relating to a general theme.
- arranging ideas in an appropriate sequence.
- considering alternate outlines for a written text.

Remembering is important to writing, especially in the beginning stages because writers plan on the basis of what they know. However, the topic alone, whether student or teacher generated, does not always provide sufficient direction for students to access what they know (Bereiter and Scardamalia, 1985, Ch.2). Using the computer to provide prompting is one way of helping students activate relevant or even oblique references to knowledge they have, which may be important in the development of their text.

Prompting about writing is a way of helping writers explore their topic. Graves suggests that as part of the process model students should:

- talk with a partner about ideas for writing.
- discuss their work with a group of students.
- talk to teachers about particular pieces of work as well as the writing process involved.

Various models for prompted writing can be implemented with computers.

One of the simplest ideas we have seen comes from Marcus (1984), who recommends that students simply swap monitors when sitting side-by-side at neighboring computers, so that Student A's monitor, still attached to Student A's machine, is on top of Student B's computer and vice versa. Student A begins thinking/writing about a topic as a part of the prewriting process and the text appears in front of Student B. If Student A loses the train of thought, then typing "???" will be a cue to Student B to provide a response such as "You were thinking about..." When ideas stop completely, Student A can type "ZZZ," and B will respond with a different view of what A has said so far, or even some entirely new suggestion. When the session is completed, the files can be printed out and used as the basis for planning or further discussion.

Teachers have always provided such prompting for their students, and many writers also ask themselves questions as they prepare for writing. Questions about both the content and the process help writers as they plan.

- Should I outline first?
- Where can I get more information?
- Who is going to be reading this?
- What would be a good opening sentence?

Using the computer as the prompter is also possible, and several software packages have been designed to prompt writers to think more about their topic. Helen Schwartz (1984) of Oakland University has produced a program called *SEEN*, which is designed to help college students in their analysis of fictional characters for literature classes. One part of the program first asks students to create a hypothesis about the character they have chosen to work on and then asks them to support and refine the hypothesis they make. In doing this, students are being helped to develop ideas about literary work as well as learning a method of analysis.

The questions asked by *SEEN* are fixed in a general sense, but each particular question is based on the hypotheses the student has created. For example, for the student hypothesis that Don Quixote is eccentric, *SEEN* would ask the student to support the hypothesis on the grounds of what Don Quixote does, what he says, and how others react. It would then go on to ask the following questions:

- What does Don Quixote do that shows Don Quixote is eccentric?
- What does Don Quixote say that shows Don Quixote is eccentric?
- How do other characters react to Don Quixote that shows Don Quixote is eccentric?
- How do other characters act (in a similar situation), and how does this comparison show that Don Quixote is eccentric?
- In Don Quixote is there a third-person narrator?
- What does the third-person narrator say which shows Don Quixote is eccentric?

Following this, *SEEN* prompts users into a phase in which they are able to refine and test their evidence and ideas by looking at contradictions and exceptions to their hypothesis.

SEEN is quite directive and is designed for a special type of writing. Another prewriting package that is a lot more open in its approach is the *Writer's Helper*, which has been designed by William Wresch (1984). The prewriting section of *Writer's Helper* consists of four subsections. These help writers choose a topic, explore the topic, organize their ideas about a topic, and develop a single paragraph. Within these subsections, Wresch presents a variety of approaches that students can use in each of the tasks.

Prompting programs only provide writers with ideas that they can use in composition. Choosing and exploring a topic needs to be accompanied by some prewriting planning and organization. Teachers have used devices such as an "Ideas Diagram" and Flower's similar suggestion of "Issue Trees" to guide students in their planning of written texts. (See *Idea Diagram* on page 62.)

Another suggestion from Flower is that students condense their ideas into as brief a statement as possible, thus being forced to sift out the major idea from the minor ones. "Nutshelling" can be a very good way to start the process of building an outline or preparing a plan for writing.

An "Ideas Diagram" can help students check the structure of their text before actually beginning the first draft. They can check for content as well as determine whether or not the writing will be structurally adequate. Outlining is best done after students have developed many ideas about a topic, so that their main concern is building and evaluating structure and content in the text they propose.

Outliners are produced for most types of computers. Thoughts and ideas can be entered randomly and a structure built up gradually. Headings will be numbered or formatted by the program and paragraphs can be inserted beneath them. These paragraphs can be hidden if the writer only wants to view the outline, and then uncover it at will.

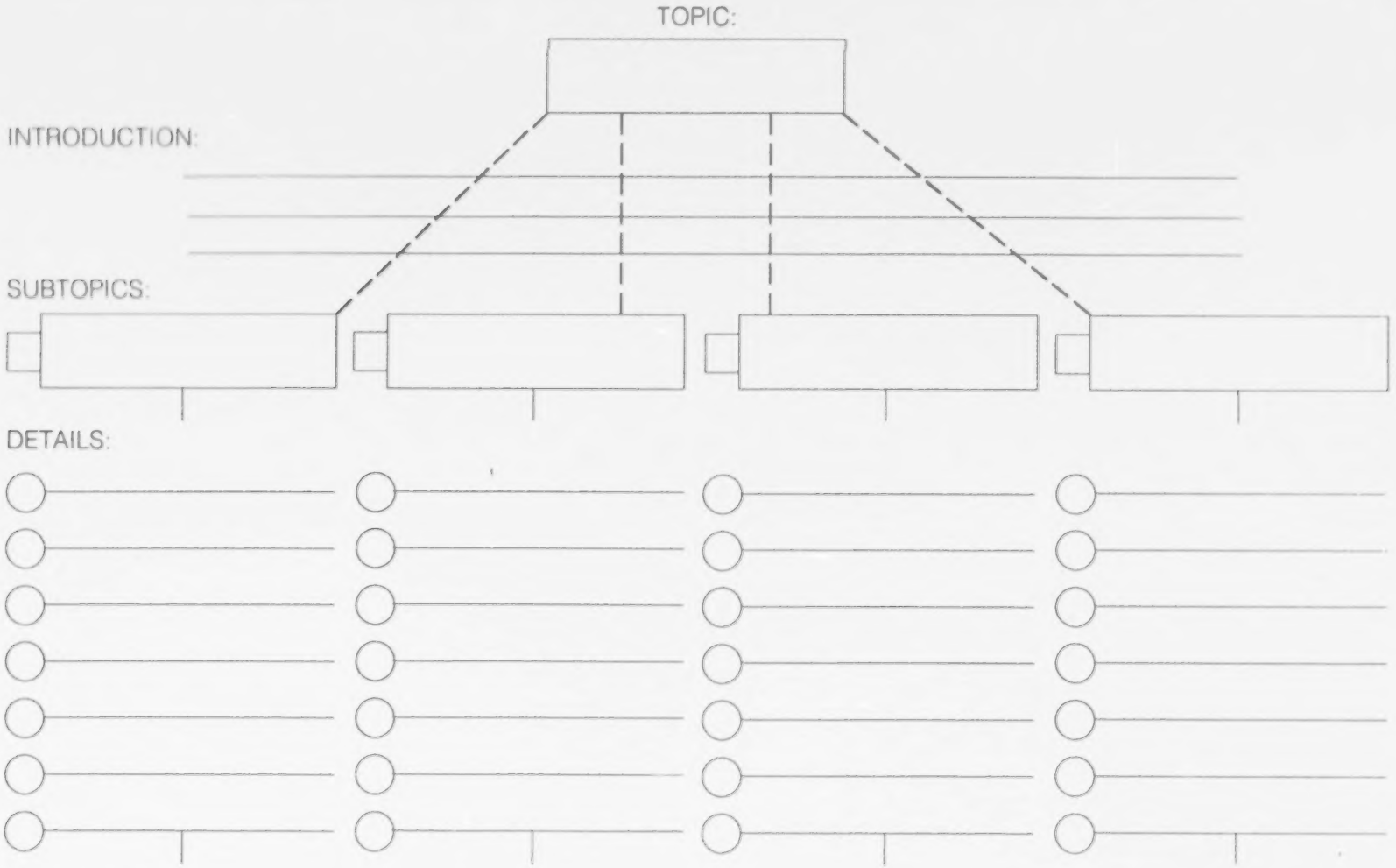
Levels Of Outlining
For Part Of This Chapter

Level 2
Electronic writing
- Introduction
- Approaches to writing
- Prewriting

Level 3
Electronic writing
- Introduction
- Approaches to writing
  - Flower's approach
  - Graves' process writing ideas
  - Summary
- Prewriting
  - Goals
  - Remembering
  - Prompting

Level 5
Electronic writing
- Introduction
- Approaches to writing
  - Flower's approach
  - Graves' process writing ideas
    - **Prewriting**
    - **Composing**
    - **Revising and editing**
  - Summary
- Prewriting
  - Goals
  - Remembering
  - Prompting
    - **Prompting about...**
    - Marcus' screen swapping
    - Teacher talk
    - SEEN

IDEA DIAGRAM



University of Kansas, Institute for Research in Learning Disabilities. From Mulcahy, Marfo, Peat, and Andrews, 1986, p. 139

A similar, but more formal, formatted outline can be used as the basis for documents time and again. Such an outline is called a template and is most likely to be constructed directly on a word processor. A typical example would be the production of a book review in middle school classes. The teacher might set up the following format for students. (See *Book Review form* on page 64.)

Students can then load the template into the word processor they are using and use the headings as the basis for gathering and organizing material they will use in the review.

Research indicates that writers need to be able to move easily among the various stages of writing since the writing process is essentially an integration of them all. During prewriting, students define, explore, and structure the material they have about a topic. They may use databases, friends, or teachers as sources of help and information.

COMPOSING

While this section on composing was being written, we realized that we should include some material on the usefulness of formatted outlines as a prewriting aid. It was a simple matter to move to the previous section and compose a paragraph at what seemed the most appropriate place. This ability to insert text neatly and easily is one of the advantages of using a word processor to compose.

Inserting means that writers can compose from outlines they have set up for themselves. After loading an outline from disk or creating it on the word processor, students are able to build up the material under each heading they have written. For example, students who have gathered material for the book review format outlined in the previous section can simply load the formatted outline and type in the material they have for each heading. The process of inserting text can sometimes be easier through the use of a two window feature in word processors. The file that contains an outline can be shown in one window, and in the second window the writer can work on expanding the headings.

In some word processing environments, it is possible to have several separate files open at the same time. One graduate student we know keeps three files open when she is working:

1. the document currently being written,
2. a "scraps" file into which all major deletions are moved in case they are needed later, and
3. an "ideas" file on which she keeps track of things which she is reminded of while writing. They may be of value to her current composition, but have no immediate relevance.

This student is making good use of the word processor's capabilities to assist her in writing. She is using the computer for evaluation and exploration. The deletions file is checked after a lengthy writing period and read through with the composed text in mind. Often some deletions seem to be important in a different part of the text and can be moved back into it without lengthy retyping. Deletions are also a useful reminder of aspects of the composition that the writer felt were not essential or not well written and are used as a check on both content and process goals.

As the writer generates ideas, he or she should refer to the text outline. If the ideas fit into the current outline or suggest new lines of argument, they are used; otherwise, they are deleted.

In the same way that it is possible to move between and combine word processing files, it is possible to integrate word processor, database, spreadsheet, and even graphics facilities. Writers can view the database or spreadsheet and move from viewing to writing with a word processor. It is also possible to move parts of the database or spreadsheet over to the word processor and print them in the document.

Such a facility is useful for students who need to back up arguments in reports and articles with tables, graphs, and financial projections. Despite this usefulness, research indicates that students may be unwilling to use the integration process. Ayres and Nolan (1987) report on a project in which students used an integrated software package (*Enable*). Although they learned how to place graphs and spreadsheet views into word processed reports, most students preferred to accompany a final report with separate sheets of tables and graphs.

Nevertheless, the students in the project still used the skills of analysis and synthesis as they worked with the computer. This is evidenced by the fact that they were able to include material from several sources as part of the report. What they did not do was use software integration features to form final documents, choosing instead to print from each separate program. Use of integration features may arise, however, through greater experience with the package.

In summary, the word processor allows students the flexibility to use outlines and templates effectively and to move freely within the text to insert and delete. Some software packages enhance the writer's ability to analyze and combine information during composition, either from a series of word processing files or other information-based sources.

BOOK REVIEW *NUMBER 1*

Who were the main characters in the story? _____

_____

Where does the story happen? _____

What kind of story is it? (For example: Adventure, Mystery, Science Fiction) _____

What is the story about? Try to give a brief summary. _____

_____

_____

_____

In the box below draw an illustration about the most interesting or exciting part of the story.

Source: Keith and Lyn Solomon. (1974). *Exploring the library*. Hong Kong: Martin Educational.

What is happening in your illustration?

_____

_____

_____

_____

_____

_____

Why did you/did you not enjoy the book? _____

_____

_____

BOOK	*INFORMATION*
Title:	
Author	
Call Number	
Fiction/ Non Fiction	
Publisher	
Year	
Place	
Illustrations	
No. of Pages	

MORE BOOKS BY THE SAME AUTHOR

REVISING AND EDITING

The acts of writing a piece and revising it are usually so closely integrated that it is very difficult to separate them. In the same way that people check for sense and evaluate for meaning as they read, writers keep a constant watch on the material they are writing, mixing revision with composition. As we have stressed, this self-monitoring is a vital part of the problem solving process.

Writers carry out their own evaluation by checking writing against goals and plans they set down for themselves in their prewriting activities. When a draft seems complete they might ask themselves:

- "Does this paragraph really convince the reader that..?"
- "Have I moved smoothly from stating the pros to stating the cons?"

Sometimes they may want to evaluate earlier plans:

- "Is this really the order I want to make those points in?"
- "I don't think that material on...is all that relevant."

Other sources of comments and feedback can help the revising writer. Readers, as well as some types of computer software, can provide writers with information that helps them turn a draft into a well composed final text.

One of the problems that faces writers revising their work is that they sometimes have difficulty finding their own errors. This is why it can be important to have the opinion of another person. Having a friend or colleague read a paper you've just written can be an eye-opening experience. Comments such as

- "What do you mean by...?"
- "Gee, I like the way you've written that."
- "The argument you make in that paragraph is really good."
- "Do you know how many times you spelled advice wrong?"

made by a friend or collaborator in a supportive way, are a good source of revision material. Not only will they provide positive feedback about portions of the work and information about errors of various types, but they also give the writer a view of the text from a reader's perspective. As writers discuss the reader's view they can at last get some idea of whether or not the goals they set down have been achieved.

This type of commentary is usually done face to face as a writer and a reader sit down and talk over the piece of written work. A word processor can be useful in this process. Comments can be made, discussed, and stored on another file or else inserted into the text at the appropriate place. Programs are available, such as *Writer's Workbench*, that allow editorial comments by various readers to be viewed or hidden. The computer thus serves as an adjunct to the writer's memory and as a useful aid in the evaluation process.

There are also computer programs that can be used to analyze aspects of student writing and provide feedback to the writer. Most common in schools are spelling checkers and thesauruses. These editing aids are normally used once the writer feels the text is nearly finalized and its organization is satisfactory. Other programs give information about the structure of the text, checking such things as use of passive voice, readability, sentence length, and word usage. While such information is often useful in revision by college students, beginning writers need the assistance of teachers to help determine the meaning of much of the analysis. The usefulness of text analysis programs is quite dependent on the growth and skill of the writer and such programs are not very advanced. While spelling programs do a good job, grammar checkers often make suggestions that are incorrect for the given context.

So far we have focused on ways to help writers evaluate their work. The mechanics of revising are also important. The computer environment provides the facilities that make it possible to avoid the often messy and usually tedious adding and deleting, cutting and pasting, and rewriting of the pen-and-paper environment. It is this aspect of word processing that students find especially valuable. The word processor enables learners to carry out revising activities quickly, so that revision becomes a valuable part of the writing process instead of the tiresome activity it can otherwise be.

The word processing commands most commonly used in the revising process are those that allow writers to:

- search for a particular word or phrase.
- find and replace words or phrases.
- move blocks of text.
- delete sections of text.

Research indicates, however, that students do not necessarily use these word processing commands even though they are known to be available. The place of the teacher in explaining the reasons for revision, the ways of revising, and the function of the word processor in the revision process is still essential. You can:

- show students how to move and delete blocks of text.
- give lessons that illustrate the effect of moving sections within a text.
- discuss over-used words and show how the word processor can be used to find them.

Finally, it is useful to remember that writers have their own style of prewriting and planning, composition, and revision. Our focus has been on a problem solving approach and the development of thinking skills. Despite technical sophistication, good writing still depends on teachers and students working together to develop strategies and skills within the writing process.

WRITING AS A SOCIAL PROCESS

We have talked about the importance of social aspects in the development of thinking skills and ways that computers can be used to promote effective working relationships between students. In writing, for example, computers can facilitate communication through electronic networks such as bulletin board programs and electronic mail systems. Daiute (1985) reports on the way in which writing a school newspaper can be made a more collaborative and simple process within a computer based writing environment. As she comments, "The newspaper activity on the computer is also popular because it is a team effort and it uses publication tools. Without a computer, the physical activities of writing a newspaper are much more cumbersome" (p.177). The *SEEN* program mentioned earlier lets students read and post notices about the fictional characters students are discussing, so that hypotheses may emerge as a result of collaboration.

Working together is not always a valuable experience. Consider this:

> One collaborative arrangement adopted by two girls writing a Logo program was: "I'm the thinkest, you're the typist." While this got the work done, it was not a particularly good way of incorporating each other's skills, nor was it an effective interaction for learning (Sheingold, Hawkins, & Char, 1984, p.59).

Students need to learn the social skills that will enable them to cooperate in solving problems and in using each other as resources. This may require appropriate guidance from teachers.

Writing as a social process can be enhanced within a computer environment. But it seems that a main factor is the teacher's philosophy and the instructional and organizational practices that are put into effect. When teachers view writing as a communicative task, they are more likely to allow students to collaborate on texts, talk about the meaning of sentences and paragraphs, and question the way a passage is written. By doing this, you can promote development of your students' thinking skills.

SUMMARY

Using computers within writing is an ideal way for teachers to help students develop effective learning strategies and thinking skills because:

- the focus can be upon the writing *process* not just the *content*.
- the process writing steps encourage students to reflect on their thinking.
- teachers act as guides and facilitators. They are free to consult with students using the models provided.
- electronic writing can be a social process. Students have an opportunity to develop both written and spoken communication.
- writing with the computer is fun. It provides a socially interactive and reflective learning environment.

Chapter 8 COMPUTER COMMUNICATIONS AND THE DEVELOPMENT OF THINKING SKILLS

The ability to send electronic messages anywhere in the world within seconds has opened up a new era of communication. It is now possible to communicate directly from the classroom with people in different cultures who speak different languages.

There are examples from all over the world of the innovative ways in which telecommunications is being used in schools.

> "Students at Turramurra High School in Sydney, Australia have been communicating with Eskimo students in Alaska for nearly two years now." (Frederick, 1985)

> "This exchange made the students in Tokyo, who were having trouble expressing their ideas in English, the experts while students in San Diego tried to express themselves in Japanese." (Riel, 1987)

For more examples on how computer communications are being used in education see *The Computing Teacher*, special issue on Telecommunications, April, 1987 and April 1988.

In this section, we would like to illustrate how computer communications (telecommunications) can best be used to promote effective learning and thinking. The ease with which children can read, write, and receive material from other schools in their same town, country, or anywhere in the world provides very powerful motivation for a whole range of learning activities in the classroom.

TYPES OF COMPUTER COMMUNICATIONS

The basic elements in the communications link are the computer, modem, and telephone.

There are several ways to communicate by computer. These include:

Screen to Screen. This term means that whatever appears on one monitor will also appear on the monitor of the linked computer(s). The link may be within classrooms, within a school, in the local area, or around the world.

Intermediary Computers. A constraint of direct screen-to-screen contact between computers is that both users must be available at the same time. Many communications systems (e.g., CompuServe, Envoy 100) make use of an intermediary central computer that acts as a store and clearing house for messages. Intermediary computers offer a number of options:

Electronic mail provides us with the opportunity to send messages to a contact person via an intermediary computer. The central computer functions rather like a post office private box system. Each user has a mailbox into which mail can be sent from other users. Mail can be collected and read at any time by logging onto the central computer. Mail can be sent to any other mailbox within the computer, or within any other computer system to which it is linked. The major difference between this and the traditional mail system is that computer mail arrives in your computer mailbox just moments after it is sent.

Bulletin Boards are a place for information exchange on a computer system. They are just like the bulletin board in the school staffroom. Messages can be posted and read. For example, if a teacher wants to know which schools are using desktop publishing, she can quickly search for the information or ask other schools to contact her. Students can use bulletin boards for exchanging information and posting news items.

Online Chats provide a chance for users to "talk" directly with each other at an agreed upon time. This can be used for individual or group discussions via the intermediary computer.

Teleconferencing enables users to hold a meeting on the computer. The advantage of this is that a person can participate in a meeting at a time and place that is convenient.

Databases are stored collections of information and provide either bibliographic or full-text material (Eric Microsearch, The Source, Knowledge Index). Bibliographic retrieval databases provide information on title, author, publisher, publication date, and in some cases, an abstract. Full-text retrieval databases provide online printouts of various lengths. In addition to commercial databases, an increasing number of local special interest databases and bulletin boards are being developed by teachers.

HOW TO USE COMPUTER COMMUNICATIONS AS A LEARNING TOOL

It is important to have a *definite goal* in using computer communications as a learning tool. Much of the initial enthusiasm for the technology has waned because people did not have a clear idea of how to use it in the curriculum. It is our experience that it is important to have some purpose and structure in order to get the most out of communications.

We carried out a project that linked a rural school in New Zealand with a large city school in Calgary, Canada. Students were fourth, fifth, and sixth graders. At the beginning we simply arranged for each student to correspond once a week with a person at the other school. This was exciting for the students initially, but it soon became clear to us that students would need some guidance if there were to be any learning benefits.

Our approach was to assign each student a contact person at the other school. Students were then assigned to groups, and each group was made responsible for a specific topic. The topics were related to various aspects of each country (e.g., weather, geography, social customs, language, dress, culture, leisure activities, etc.). Groups were assigned a topic during a particular week with the contact person responsible for establishing communication. Students would work in their groups to frame questions to be sent to each others' schools. The group would then send for information, and when this was received, they would prepare a report for presentation to the class. By giving students responsibility for their own communications, a number of learning opportunities were provided. These included learning to:

- work cooperatively.
- make group decisions by concensus.
- give oral presentations in class.
- locate facts and recognize details.
- ask relevant questions.
- compose material in a way that is understandable to others.
- use maps and texts to obtain information.

You will find that most successful projects have been carefully planned and structured to take account of specific learning outcomes. Following are some suggestions on how to teach effectively with computer communications.

1. *Integrate the communications* into an existing theme or subject area. For example, use it within a social studies module or as a language arts activity.

2. *Plan a unit of work* around the computer communications. For instance, it is a good idea to do research using texts and other references in order to arrive at problems and information needs that might best be met by the computer.

3. *Encourage students to identify their own information needs* and to take responsibility for researching specific topics. Remember to give them lots of opportunities to control their own learning.

4. *Divide the class to enable small group activities.* Help to facilitate group discussions so that all students have a chance to verbally participate.

5. *Plan the computer communications carefully.* This may involve a lot of personal research to locate other contact classes or information systems. Also, if you are communicating with another school, it is important to have some mutual aims and a common set of procedures. The best way is to have specific topics and contact people who are responsible for the communications.

6. *Give the communication process sufficient time to work* and to be integrated into the school program. It may be necessary to do a project over several weeks or months to develop meaningful interaction with other

schools. For international projects, we have found that it is best to communicate once a week. This provides adequate time for composing answers to questions and for group collaboration.

7. *Use computer communications as an ongoing class theme and project.* This might involve exchanges of videos, photos, posters, and written materials between students. It is a good idea to place these materials on notice boards in the class and to create a learning environment that is focused on the personal communications.

8. *Hold regular feedback sessions with individuals and small groups.* Guide them to work effectively within groups, collecting and analyzing information, preparing reports for verbal presentations, and using texts and other materials (videos, movies) to obtain information.

Computer communications provides students with an enormous amount of motivation for writing. There are many opportunities to develop skills in typing, reading comprehension, written composition, and oral communication. At a personal level, students begin to feel that they are in control and are responsible for the decisions they make.

Because computer communications can be expensive and may be limited by the amount of equipment available, it is best to use it in situations where the computer can provide *better learning opportunities* than other methods. For example, learning about other cultures and languages is likely to be best provided through direct interactions on the computer.

THE STUDENT'S ROLE IN COMPUTER COMMUNICATIONS

A thinking skills approach to computer communications has implications for the ways in which students will participate in the teaching and learning process. First, students will be required to take increased amounts of responsibility for their own learning. For example, they will need to initiate letters and participate in online activities such as teleconferences and bulletin board exchanges. Second, students will need to know how to access and manipulate information contained in databases and filing systems. This will call into play a large number of information processing skills that have already been described in the database section of this book. These include researching the problem, collecting and organizing information, identifying important facts and relationships, summarizing data, formulating hypotheses, and making predictions. Third, the electronic writing process encourages students to clearly articulate their ideas in terms that are understandable (and scrutinized) by a large audience. The provision for public presentation of ideas may, in turn, provide students with ready access to feedback from their peers and from the teaching staff.

Overall, the highly interactive electronic medium potentially requires a much more active role for students than other conventional approaches to learning. This will require some modifications to the school curriculum and an understanding on the part of teachers about their roles as guides and facilitators of learning.

THE TEACHER'S ROLE IN COMPUTER COMMUNICATIONS

Corresponding to the changes in the student's role described above, the role of the teacher will undergo some major changes. This will be especially evident in the way teachers interact with their students. The teacher's role in computer communications is illustrated in the following diagram. (See *Telecomputing The Role of the Teacher* diagram on page 70.)

As a *Participant*, the teacher works alongside the students to

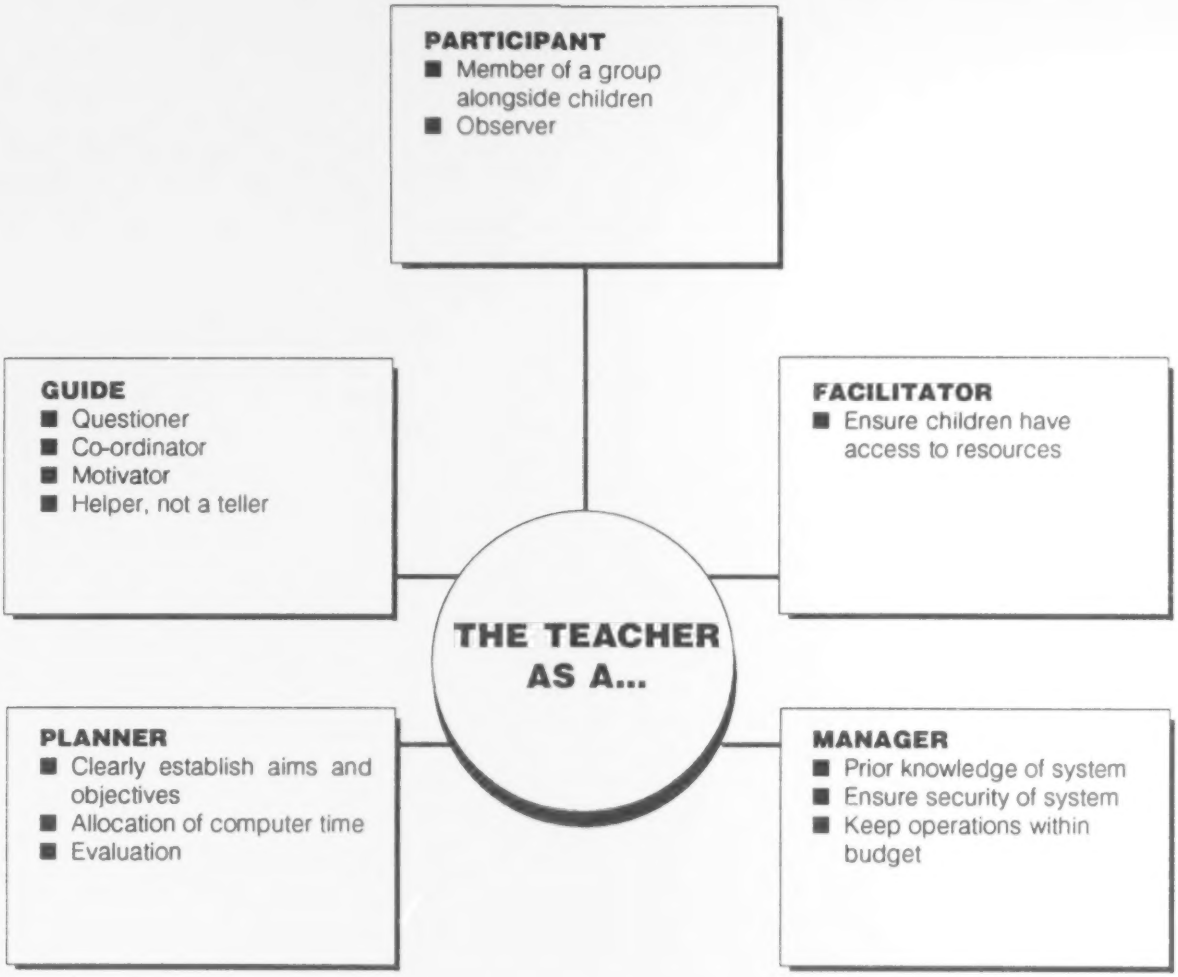
- help form questions and messages.
- analyze and prepare incoming messages for class presentation.
- send messages on the computer.

As a *Facilitator*, the teacher

- encourages active participation by all students.
- moderates group discussions.
- promotes verbal presentations.

As a *Manager*, the teacher

- learns how to use the system efficiently and economically.
- assigns students specific duties.
- keeps the project on schedule.



Adapted from: Computers in Education Development Unit (1987). *Interactive Fiction and Computers.* Wellington: Department of Education.

As a *Planner*, the teacher

- ensures that students have fair access to the system.
- relates aims of the project to the curriculum.
- evaluates the teaching and learning outcomes.

As a *Guide*, the teacher

- uses effective questioning strategies to prompt thinking.
- motivates students to become teacher-independent thinkers.
- helps students to put problems and ideas into their own words.

By fulfilling this role, the teacher can create a learning culture that transcends subject area boundaries and is based on students' real life experiences.

In the process of teaching and learning with students, a basis can be established for the development of "more articulate, effective and honest teaching relationships with students than is usually possible in either conventional classrooms or with conventional computer assisted instruction" (Papert, 1980).

THE COMPUTER'S ROLE IN COMMUNICATIONS

New communications technology has greatly extended the range of computer uses in the school curriculum. Whole class projects can be undertaken with a single computer. Computer time can be scheduled so that all students have equal access. The computer lends itself to a cooperative learning strategies approach (described in Chapter 4).

Remember to keep the focus on *how* students can use the technology rather than *what* the technology can do. The role of the technology is simply to enable human performance. It is more important to be able to say "My students are great because they have learned how to send prepared datafiles via the system," than to say "The system is great because it lets my students send prepared datafiles."

CASE STUDIES USING COMPUTER COMMUNICATIONS

Developing Conversational Skills

In this study, computer communications was used to help develop the conversational skills of a hearing impaired student. For this child, a whole new means of communication was suddenly available to him.

A computer with a modem was set up at the teacher's home and at the home of the student. On two evenings a week the teacher and student took turns dialing each other at a pre-arranged time. The student was first briefed in the technical use of the communications program. He was then informed that the communications would be in the form of language homework. Two trial sessions were undertaken at school to ensure that the procedures were clearly understood.

A conversation then took place on the screen. This was followed by a brief analysis of the session on the phone between the student's father and the teacher at the same time as the student was printing out a copy of the session. Later the teacher used a word processor to edit the conversation to include a reference title and to edit out typographical errors. This version was presented to the student at school the following day.

A total of 21 sessions were held. Fifteen of the sessions were analyzed according to the number of sentences, mean length of utterance, number of conversational questions, and number of conversational statements expanded upon. A comparison of the first and the 14th session showed a large increase in the number of utterances (17 to 33), and many more conversational questions used (from 0 to 11). An increase in the complexity of sentences, and in the number of sentences that were grammatically correct was also evident.

It is believed that through these conversations and the constant role model reinforcement, the student had an opportunity to use complete sentences and hold "normal conversations" in a way that has never before been possible.

While the use of communications in this way was obviously beneficial for a hearing impaired student, the same principles hold true for all children. The requirement that students use text to initiate and sustain interactive conversations can be a powerful learning tool across the school curriculum.

(Extract from 'Computer Communications in Education'. Wellington: Computers in Education Development Unit, Department of Education, 1988.)

Collaborative Online Learning

Computer communications has helped to bridge the distance between two isolated rural schools in New Zealand. Following are examples of projects they undertook:

- *Interactive writing including prose and poetry*. Based on the pick-a-path (branching story) concept, schools used a common character and each group contributed alternative solutions to the character's situation. These were then combined to form a complete story and saved as a file that was transmitted to the contributing schools. A similar approach was used for poetry. These activities were ongoing and integrated into the teaching program each week.

- *Combined writing of radio plays*. This was provided as an extension activity for a small group of above-average students. The students designed their own characters in consultation with their counterparts at other schools and drew up an overview of the plot. Off the screen, each group then developed the action of the play and came together online to discuss the developments and transmit to each other their prepared drafts.

This type of online collaboration really extends many of the thinking skills approaches already discussed in the previous section on games, adventures, and interactive fiction. In these projects, students were required to use a full range of thinking skills and to collaborate with students both in their own class and online with other schools.

(Extract from 'Computer Communications In Education'. Wellington, Computers in Education Development Unit, Department of Education, 1988.)

Teleconferencing As A Learning Tool

High school students have been using teleconferencing facilities to practice their New Zealand Maori language and to hold meetings on cultural and historical topics. Maori studies students in several local high schools communicate via a university-based teleconferencing system. This gives them several facilities, including:

- a *bulletin board* for posting messages that give information or seek assistance.
- *electronic mail* so they can communicate directly with one another on topics of personal interest.
- *access to the university library computer* for checking references and the availability of books.
- a *teleconferencing system* that allows them to convene special interest meetings or to hold open discussions with all users.
- a *news service* that informs them of upcoming events.

Using computer communications in this way gives students control over their learning and more opportunities to interact with other students and teachers than would be possible in a regular class. For example, Sally at school A can practice her language skills by chatting with Tom at school B. Peter at school C can send his essay to Gerry at school D. Roger at school B can put a request on the bulletin board seeking assistance in locating a journal article. Jane at school A can convene a special meeting for those interested in studying about family life. Teachers can hold a teleconference to exchange ideas and do course planning.

Computer Communications and Newspapers In Education

Thirty-eight New Zealand schools, along with several more Australian and European schools, participated in an international newspaper day. Project "Interlink" culminated in the preparation of school newspapers using selections of articles exchanged via electronic mail. There was a great deal of excitement in the participating schools as students sent and received articles from New Zealand and overseas.

In one school, junior high school students had prepared for the day by spending hours in the preceding weeks preparing, writing, and editing articles for the paper. Students and teachers explored together the intricacies of the new technology as they used their modem to transmit contributions to the central bulletin board. The excitement grew as they scanned the central bulletin board and saw their own work along with that of students from around the world.

Children of eight years and above at an elementary school worked in groups and as individuals on their writing, and at regular intervals discussed their progress with the rest of the class. Some wrote drafts on paper while others composed articles at the keyboard. Eight articles were selected by popular choice. The authors saw their articles sent and took home a printout. A booklet containing all of the school's contributions was produced and circulated among the children.

The event planners had hoped that the communications link would stimulate the production of school newspapers throughout the country. In one city, sponsorship was obtained to allow for an eight-page tabloid to be published. The 20,000 copies were distributed to all schools in the country.

(Extract from 'Computer Communications in Education'. Wellington: Computers in Education Development Unit, Department of Education, 1988.)

SUMMARY

Computer communications provides an exciting environment in which students can direct their own learning. The requirement that students communicate with a wide audience helps to encourage the development of collaborative learning and writing skills. The interactive nature of the technology means that teachers can give more attention to facilitating learning through consultation with students, rather than expository teaching. It is through these kind of real-life experiences that students learn to become effective thinkers and communicators.

Cognitively, computer communications causes students to reflect on their thinking. They have to work out problems for themselves, explore different solutions to problems, do research, analyze and plan their work, and look back to evaluate their own progress. Socially, they must participate in group discussions, clearly articulate their ideas, and work cooperatively with others in the class or online. To be effective, computer communications projects must be very carefully planned and integrated into the school curriculum.

Chapter 9 DATABASES AND EFFECTIVE THINKING

Using databases as tools for learning provides opportunities to focus on learning strategies and thinking skills as well as to explore and discover facts about a particular topic. In this chapter we focus on the learning process in a database-using classroom and discuss ways of working with databases that put strategies and skills on center stage.

UNDERSTANDING DATABASES

A database management program is a general purpose tool that lets you design, build, and access collections of information using a computer. With the same program, you can create and use files of information on any subject (e.g., types of cars, climate information, student grades, and famous poets). Each file of information is called a datafile. Information is put into the datafile in a logical and systematic way so that it can easily be retrieved and analyzed later on.

The ways in which data is stored and organized in a database can best be illustrated with some examples. Figure 1 shows that, like a filing cabinet, many datafiles can be stored on computer disks for use with the database program. The information within each datafile is organized in much the same way as a set of index cards. Each datafile contains collections of items of a particular kind, for example, items about birds or items about TV programs. Figure 2 shows that each item in a datafile is called a record. All of the information about a particular item is put into that record. In the example, each record contains information on the climate of a particular town or city.

Each record contains categories into which the information is divided. Figure 2 shows the categories of information within a New Zealand climate datafile. Each item of information within a record is called an entry. The entries within the record for Alexandra are shown in Figure 3.

When using a database program, you can view all the information for each record as if it was on an index card and turn easily to the next. Some databases also allow information to be presented in a multi-record layout so that information for all records is displayed in list form under the category headings. The ability to display information that is grouped in this way is a huge advance over a simple filing system.

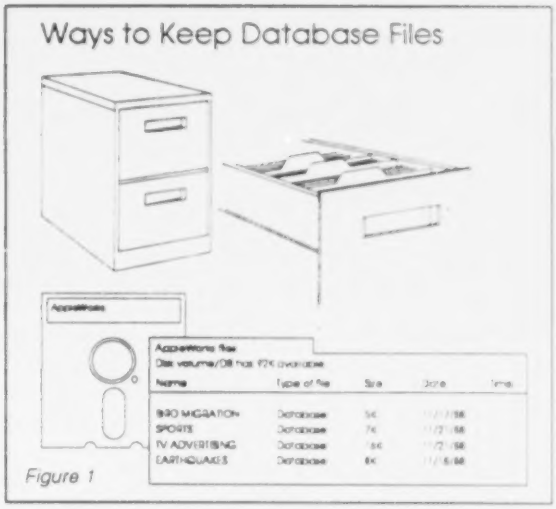


Figure 1

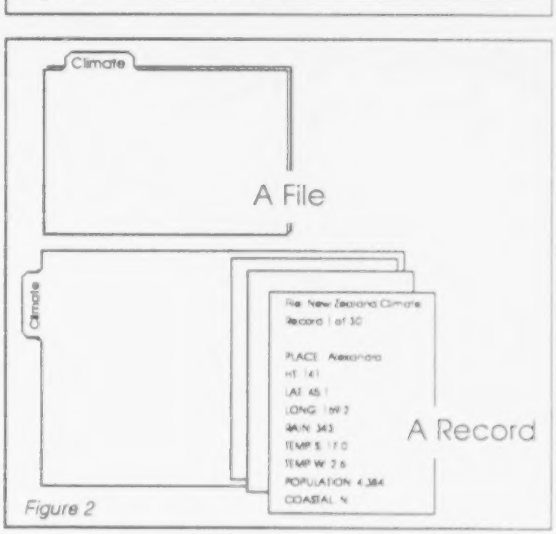


Figure 2

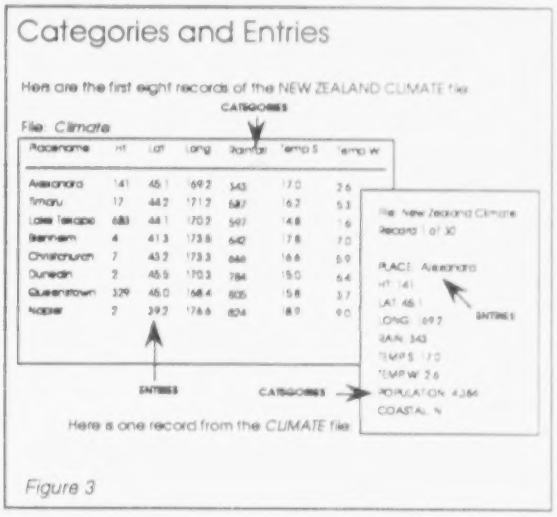

Categories and Entries
Here are the first eight records of the NEW ZEALAND CLIMATE file
CATEGORIES
File: Climate
ENTRIES
CATEGORIES
Here is one record from the CLIMATE file

Figure 3

WHY TEACH WITH DATABASES?

With this understanding of databases as background, it is fairly easy to see that there are several purposes for which databases are used in schools. Hunter (1985) provided a brief list of broad strategies relating to data manipulation and investigation in the first worthwhile attempt to relate database use to education. The list of learning skills and strategies that follows is based on Hunter's ideas, but has been expanded to include the area of social skills.

Skills And Strategies Practiced With Database Lessons

- Exploring data
- Relating information to one's own needs and interests
- Seeking different relationships, new ways of looking at things
- Defining questions, concepts
- Breaking down problems into smaller components
- Writing down the plan off the computer before seeing if it works
- Classifying, categorizing
- Analyzing relationships
- Comparing and contrasting
- Discovering commonalities or differences between groups of events
- Ordering and arranging information
- Looking for trends
- Taking notes of what happens as the plan is actioned
- Synthesizing the answers to subproblems to solve a bigger problem
- Assessing the adequacy of an answer
- Repeating the problem solving process to improve its outcome
- Arranging information in more useful ways
- Talking about thinking
- Observing other people's methods of operating
- Learning to adapt strategies for different tasks
- Becoming aware of a variety of strategies for handling different tasks
- Learning how to divide up jobs to suit individual talents and interests
- Learning how to best assist the weaker members of the group so that they participate and practice important skills
- Learning how to articulate problems and finding ways of explaining clearly

Of course, many of these purposes could be achieved by students in the noncomputer classroom. But at what price? The speed and information handling capabilities of the computer allow students to pose questions that they may never have been able to investigate before. Further, while the computer handles the work of data retrieval and processing, the students are able to focus on their own problem solving techniques and thinking skills. Before the computer, there was no machine that could do such things, and the time involved in complex data manipulation meant people rarely undertook such tasks.

THE TEACHER'S ROLE IN USING DATABASES AS A LEARNING TOOL

The important elements of a teacher's role in computer learning environments were covered earlier. Here the intention is to highlight some aspects of the teacher's role specifically in relation to database use.

Teacher as Planner

The database lesson must be linked to subject matter related to the curriculum.

Become familiar with the operation of the database, experiment with various database and lesson ideas, and consult with other teachers who are using databases.

Teacher as Facilitator

Be familiar with the subject matter being studied and know enough about operating the database program to be able to assist students having difficulties.

Use questions to check understanding and to direct attention to aspects of the material or process that may be the source of a problem.

Teacher as Guide

Rather than direct students, use analogies or questioning strategies to guide students to a higher level of thinking or to the application of a different strategy.

Incorporate the thinking and problem solving strategies that are the basis of the database lessons into contexts that do not include a computer so that students can see that such techniques can be used strategically throughout their lives.

Teacher as Manager

Prepare the necessary disks and classroom resources. Remember that access to outside information sources will almost certainly be required.

Expect unforeseen requirements—especially when students take responsibility for decisions about tasks and methods.

Make sure there is a sense of closure, that projects reach a conclusion.

Teacher as Participant

Accept assistance and ideas from students as part of the collaborative environment.

Don't take over. Have the students' fingers on the keyboard, not yours.

(See *The Teacher's Role in Using The Database as a Learning Tool* chart on the next page.)

The teacher plans, manages, facilitates, guides, participates, and models skills. The focus is on students' learning processes, not on the teacher's teaching expertise. Opportunities for student inquiry, problem solving, and skill development with databases are endless. With experience in using databases as learning tools, ideas will multiply and teachers will have a rich supply of potential lessons to adapt to the needs of their classes.

Students will engage in these lessons and activities more willingly if they understand the requirements and value of database use.

- The ability to use a database is a skill valued in the workforce.
- Databases involve tasks that are best accomplished by cooperative effort.
- Databases involve tasks that require the systematic application of appropriate strategies.
- A datafile is a source of information that will become increasingly important—so users must be able to judge its accuracy and adequacy.
- Students must share the resources.
- Students must communicate and interact with each other.
- Students must actively contribute to the task.

ORGANIZING THE DATABASE LEARNING ENVIRONMENT

If your students have never used a database program before, it is wiser to start by obtaining or creating a database for them rather than expecting them to create one of their own. Students need to have an opportunity to consider questions related to the planning and design of databases before attempting to carry out such an activity.

The process of getting to know about database use can be broken into three stages (Hunter, 1985). In the first stage, students use a database that has been created by someone else. In the second stage, students build a database in which the record format has been designed and tested by a teacher. The third stage consists of students investigating the database subject and then designing the record format for themselves prior to the building and use activities. By expanding the first stage activities, it is possible to more fully describe the way some thinking skills can be developed within the context of database use. We consider database use and the development of thinking skills by looking at the following areas:

1 a) Using exploration to set specific goals for investigations.

b) Planning ways to manipulate the database to retrieve hard or soft copies of information required.

c) Checking and interpreting the information produced in response to database queries.

2) Building a database from a shell.

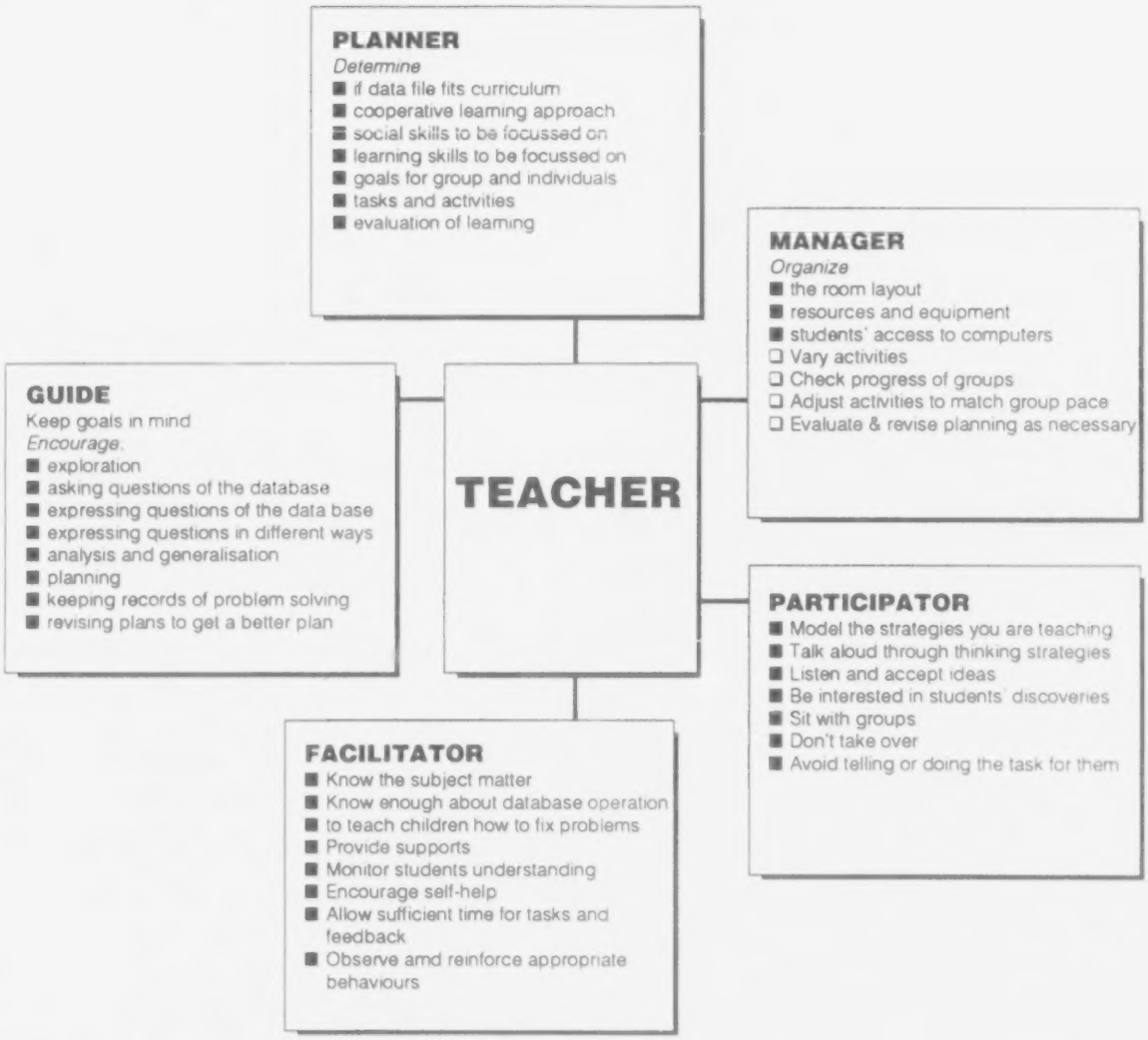
3) Designing and planning a database from scratch.

TEACHING AND LEARNING ACTIVITIES

Using A Ready-Made Database

When any database is used for the first time, students will initially need to explore and familiarize themselves both with the way the file is set up and the information it contains. This exploratory browsing is an important preliminary stage of data manipulation that should not be merely a "page turning" exercise with students flipping from record to record.

There are two main functions of this exploratory phase. The first function is to let students acquaint themselves with a new body of information at a fairly general level. The second function is to have students formulate some initial questions. This is an important aspect of database work, as it is directly concerned with the goals that students are setting for themselves. These goals are likely to be fairly wide ranging, and students may need help to turn them into specific questions. As students identify the initial questions important to them, they will be setting the goals for their problem solving activities.


PLANNER
Determine
■ if data file fits curriculum
■ cooperative learning approach
■ social skills to be focussed on
■ learning skills to be focussed on
■ goals for group and individuals
■ tasks and activities
■ evaluation of learning
MANAGER
Organize
■ the room layout
■ resources and equipment
■ students' access to computers
❑ Vary activities
❑ Check progress of groups
❑ Adjust activities to match group pace
❑ Evaluate & revise planning as necessary
GUIDE
Keep goals in mind
Encourage:
■ exploration
■ asking questions of the database
■ expressing questions of the data base
■ expressing questions in different ways
■ analysis and generalisation
■ planning
■ keeping records of problem solving
■ revising plans to get a better plan
TEACHER
PARTICIPATOR
■ Model the strategies you are teaching
■ Talk aloud through thinking strategies
■ Listen and accept ideas
■ Be interested in students' discoveries
■ Sit with groups
■ Don't take over
■ Avoid telling or doing the task for them
FACILITATOR
■ Know the subject matter
■ Know enough about database operation
■ to teach children how to fix problems
■ Provide supports
■ Monitor students understanding
■ Encourage self-help
■ Allow sufficient time for tasks and feedback
■ Observe amd reinforce appropriate behaviours

In database terms, defining a problem is best thought of as refining broad goals into database queries. This is best done away from computers. Students need to be able to concentrate on the process of formulating these questions away from the possibility that each could be tried out as soon as it is thought up. During this process, the teacher should provide feedback on the specific questions chosen, on the value of the students' evaluation of their choices, and on the usefulness of revisions.

Teachers can facilitate and guide this goal setting process. For example, they may:

- ensure that students understand what they are aiming to do.

"Which categories contain information to help answer that question?"
"Why did you choose to arrange the data by that category?"
"Are you wanting to concentrate on similarities or differences?"

- encourage reflection on problem statements.
"Will any other categories have data useful for this problem?"
"Had you thought of arranging the data in some other way?"

- suggest that students break their questions into smaller parts.

A related part of the exploration process is prediction and hypothesis forming, which students carry out as they consider the possible answers to their questions. A question such as "Is there any relationship between population size and a country's land area?" may lead students to explore questions of urbanization and population density. It is also possible that students may hypothesize a simple relationship—"the bigger the country the bigger the population"—and only uncover any complexities later, once data has been arranged and printed.

In the process of forming database queries, students will be looking at many ways of getting answers. This analysis of the problem will involve them in the use of many different strategies. They may decide to:

- choose records from the database on the basis of a FIND command.
- select records by using key words within categories.
- arrange records chosen alphabetically or numerically.
- remove irrelevant categories of information from the screen.
- place related categories together before printing.

The actual retrieval of data sees students acting on ideas they have and is usually, but not always, a relatively easy process. Sometimes the questions students wish to ask need to be changed into a form acceptable to the software. A question from an activity on rocks, such as "Which rocks feel warm and are colored white or are colored brown?," is open to different interpretations. Is the question designed to list brown rocks as well as the white ones that feel warm, or is it meant to list the warm rocks that are either white or brown?

Students become aware of the need for clarity if they are given simple card files (e.g., a class file consisting of name, age, gender, hair color, height, weight) and work together to provide answers to questions such as "Which students are boys and are over five feet tall?" and "How many students have blue eyes and blonde hair?"

Another way of achieving the same awareness is to turn the activity into a game of "Simon Says," as a colleague of ours has done. Students stand up to show that they are a part of the answer to questions such as "Who is not taller than five feet, six inches, but is a football player or a basketball player?"

More complex questions like those just discussed need to be broken into simpler parts. So, the rocks question (the one designed to list all warm rocks that are white or brown) could be answered by combining the results of the two questions:

- "Which warm rocks are white?"
- "Which warm rocks are brown?"

Each of these two questions is easily coded into a database query and the results combined to give the desired information.

Finally, but perhaps most importantly, students need to look at what they have done, and check and interpret information they obtain from their actions. This part of work with a database necessarily also implies that evaluation and revision will take place.

The first step for teachers would be to help students understand why this is an important activity. In this way, students will become involved with the process of exploring for meaning within the print-outs they have before them. Initially, any analysis may be a matter of deciding whether or not information that has been printed out will really answer the questions the students posed. Beyond this, it is important to have students interpreting the information, making inferences about relationships they find, and reaching conclusions they feel reflect their understanding of the relationships within the data.

First attempts at this can be done using a simple example, perhaps even involving a non-computer database. For instance, students might be interested in discovering when books about home computers were published. They could do a subject search on a library catalogue recording all the dates of publication, thereby satisfactorily answering their original question. The teacher may wish to suggest other questions that arise from the printed data:

- Why are all the books so recently published?
- Why have so many been published in such a short span of time?
- Can the books published to date be divided into particular subject areas?
- What sorts of computer books may be published in the future?

Teachers can discuss with their students how such questions arise and what possible answers there may be. The students can see that data printed out may be only the starting point for further questioning. Teachers must work with their students in developing a concern for, and use of, the higher level thinking that is required after the listing and printing of information.

The excitement of such analysis is captured well by McClurg (1986), as she describes some work in her database-using class:

The question "Do all animals with a kidney also have a bladder?" resulted in various predictions. When the printout started it became apparent that fish had a kidney but not a bladder. This made sense and my students were confident that they had determined the reason. Fish live in water—they don't need a storage chamber for liquid waste. Confidence changed to uncertainty when the birds began to appear. Another search was on. The students were determined to reconcile this "discrepancy."

It's obvious that looking at printouts and carrying out any analysis is not the last step in database work. From analysis, the work will cycle back to the beginning once more, as students discover more questions and work to solve problems posed by them.

In summary, database skills needed by students will include:

- evaluating the data that is printed out.
- making inferences about the meaning of their data.
- judging the validity of their conclusions.
- testing their original hypotheses.

As students become more proficient at analyzing information and making inferences from it, they become more aware of possibilities that such activities are open to them.

Building a Database From a Shell

In a database shell or template, the teacher specifies the record categories. Thus the amount of information required to be researched for inclusion has been limited by the teacher's prior analysis of the area the database is to cover, and screen layouts (although these can be modified) will have been set out in good usable form. This still leaves students with real problems to solve.

The process of building a database is a dynamic one, subject to debate and discussion in its early stages, with ideas about category representation (keyword, sentence(s), numerical categories) changing as alternate ideas are proposed and considered. As in many "real-life" situations, there may not be a perfect solution. Rather, students will need to make a "best choice." This process gives students the chance to learn and apply the skills of data location and gathering within the context of specific requirements of the database.

There is more to building a database than obtaining data and sorting out representation problems. Questions of accuracy and verification arise both before and after entering data into the computer. Checking sources, entries, and typing becomes an important part of the building process.

Several areas pose particular problems for students. Teachers will be active in the process of working through these problems as they encourage students to explore alternatives for category data representation. You can:

- Encourage them to think flexibly and critically about later database use.
  "Good. Using bearings or compass points is fine for wind direction. Which will be more useful later? Why?"
  "How do you plan to record the color of the snakes in your database?"

- Help them become original thinkers.
  "That's a terrific way of classifying that data—the first time I've seen anyone try it."
  "That's a new problem. How would you modify what you've chosen to do, so that you could solve it?"

- Help them to debug and validate entered data by having them check their work with a partner and carry out trial searches for which they already know the answer.

Making databases is often best approached as a class project. Groups can work to solve single category representation problems and then submit them for class approval. Individuals, pairs or, again, groups of students then work to gather and enter data, which is finally available for class use.

Once students have had experience at building databases, they will have many of the skills needed to ensure that they can adequately cope with the task of designing their own databases before building and using them.

Designing and Planning a Database

The basis of a good database is a thorough understanding of questions to be answered by its use. So, the database is initially centered around students' perceived problem area and the prior knowledge they bring to the planning and decision making involved in the design process. Modification and evaluation become the key activities, however, as students seek to provide a final form for their database.

Designing a database is an interesting decision-making process. Decisions must be made about categories to be represented within each record, about the way records should be chosen for inclusion in the database, and how the screen display for a single record's information should look.

You will need to:

- Manage information resources.
- Ensure the provision of a variety of data sources.
- Help students look toward the final use of the database as a guide to its creation now.
- Encourage skills in analysis and planning.
  "Take time to think through the problem."
  "Have you listed the main questions you think you want answered?"
  "Are you comparing alternatives to work out the best points of each?"

Setting up a database can be a very valuable experience. It moves students further into the world of electronic information and at the same time provides them with more opportunity to practise using higher level thinking skills.

DATABASES IN THE CLASSROOM: A CASE STUDY

What follows is an example of how a group of students worked together using some of the skills and strategies mentioned above during a database project at school. The students were first involved in building a database about New Zealand birds, then manipulating and processing the information, and finally using it in their own project.

Building the "birds" database was an interesting decision-making process. Decisions were made about the information we should collect for each bird and how this should be represented in the database, about the way we should choose birds for the database, and how the screen display for a single bird's information should look.

This was a difficult exercise for the students. Although there were no problems deciding which headings to collect information about, the way the information was to be written under those headings caused much concern. To make comparison easier the students initially decided on a "keyword" approach (e.g., SIZE could be large, medium, or small) but soon found themselves running into problems with headings such as VOICE and FOOD. This problem was never really solved and the original ideas were modified several times as data gathering and entry took place.

The ability to control the screen layout and change it easily was essential. The students spent half an hour deciding on the most appropriate way to display the information for a single bird screen display. The end result showed that they had given a great deal of thought and attention to the way the headings were linked to each other with positioning reflecting their ideas of the relationships between headings.

The students placed limits on the birds about which they would collect information, imposing these restrictions so that a wide range of birds would be accommodated within the database.

At this stage, the students were tied to a fact-finding, answer-only approach to project work. There was little to indicate that they would use the "select," "find," and "arrange" capabilities of the database to help them, at the very least, to see communalities, differences, and trends within the data. In an effort to see what use the students might make of these capabilities, we developed the concept of the "I wonder if..." question. A brainstorming session followed and produced questions such as these:

Do any introduced birds have Maori (native) names?

Are any native birds brightly colored?

Does habitat affect nesting place?

Do birds that live in the bush (forest) all nest in trees?

How does beak shape relate to food?

These questions illustrate that students had moved away from data retrieval to a consideration of the relationships between classes of data for all the birds in the database. Questions such as these can be, and sometimes are, asked within noncomputer classrooms and explanations for answers are sought. Such questions are not common, however, because of problems with data storage, processing, and retrieval. Here the computer was managing storage processing, and retrieval, and the students were free to concentrate on what they wanted to find out.

The students now had a database and some

questions. The time for answering had come. The problem now was to ensure that the database query accurately reflected the intent of the question being asked.

Broadly speaking, the more logically difficult the question was, the harder it was for students to interpret. Not really surprising you may say, but unfortunately some of the original questions, which appeared to be very simple, were not easily turned into correct database queries.

A good example was the question "Are any native birds brightly colored?" The student asking this question tried:

NATIVE equals Y and COLOUR equals YELLOW or ORANGE

when what was needed (with our system) was the combination of the results of the two searches:

NATIVE equals Y and COLOUR equals YELLOW;

NATIVE equals Y and COLOUR equals ORANGE.

In all, about three hours were spent with the computer, answering questions and getting printouts. During that time some individual problems arose, but these were handled within the supportive atmosphere of the group.

The question of what students do with the information that results from their search is especially important. Usually the reasons behind the answers to the questions were explained in terms of the information in the database—organizing and ordering what was present. The one exception to this involved a student attempting to explain "endangered-ness" in terms of world-wide habitats—breaking away from the database, imagining all that might be there.

The final comments come directly from two of the students:

"This is different from other projects because I thought up the questions myself."

"The books we use can only give us the facts and don't muddle the information up. When we use the computer we can get different information and see how everything fits together. We'd never be able to find out this sort of stuff if we only had books." (Anderson, 1985).

DATABASE ENVIRONMENT CHECKLIST

The following checklist provides some of the questions that you might want to ask about the environment in which your students are using databases. Use it to help improve your classroom computer environment. (Adapted from Au, Horton, & Ryba, 1987)

Database Worksheets

1. Do the worksheets provide a logical sequence of data analysis steps, from the simple to the complex?

2. Do the activities encourage learners to explore the information in the database (e.g., ask their own questions and find answers)?

3. Do the database activities encourage students to plan their solutions systematically (step-by-step analysis of what they did and how they did it)?

4. Do the activities encourage students to think about their thinking (e.g., define the problem, plan a solution) before using the computer?

5. Do the worksheets encourage students to try alternative solutions to problems (e.g., arranging the data in different ways to arrive at the same answer)?

6. Do the worksheets encourage students to use systematic methods for locating and fixing mistakes (e.g., find all the occurrences of certain words)?

7. Do the worksheets encourage students to break down complex problems into smaller and simpler problems (e.g., arrange categories, study results, define selection rules)?

8. Do the worksheets promote collaborative learning and shared problem solving?

Teacher Questioning

9. Do you provide individual consultations for the students to help guide them with their problem solving?

10. Do you provide training/instruction while at the same time encouraging students to think for themselves (e.g., trying out different ways of arranging data)?

11. Do you encourage students to break down complicated problems into smaller and simpler ones (e.g., "What is the first thing you need to do to solve this problem?")?

12. Do you reinforce students for creating new ideas and solution strategies (e.g., verbal praise, class recognition)?

13. Do you provide meaningful positive reinforcement to students who engage in the use of problem solving processes (e.g., verbal praise, class recognition)?

14. Do you ask students to explain in their own words how they figured out their solutions to problems?

15. Do you encourage students to think up their own questions based on exploration of the data (e.g., "Can you think of some beginning questions that you might ask about this information?")?

16. Do you encourage students to apply the general problem solving procedures to nondatabase situations (e.g., "What types of information would you need to analyze the relationship between wind and ground temperature?")?

17. Do you encourage students to be flexible thinkers (e.g., to compare and contrast different approaches to problem solving)?

18. Do you ask questions that clarify the problem (e.g., "Tell me in your own words what you want to find out.")?

19. Do you allow time for students to answer the question (e.g., count to 5 before commencing)?

20. Do you ask follow-up questions (e.g., "Why do you think the computer selected only those records?")?

21. Do you encourage students to summarize the problem in their own words as part of their answers (stating the problem for oneself often leads to a solution)?

22. Do you help students to become more fluent thinkers (e.g., "Think of some other databases you could build. What types of information would you need?")?

23. Do you encourage students to synthesize subsolutions into a big solution? Providing linking steps to move students from simply exploring the data to examining complex relationships.)

24. Do you ask questions to encourage students to reflect on their own thinking? (Ask questions that lead to solutions without giving the answer.)

Socially Interactive and Reflective Learning Environment

25. Do you keep your hands off the students' keyboards?

26. Do you encourage students to talk about what they did and how they did it?

27. Do you provide opportunities for learners to work on problems as a group, sharing ways of arriving at their solutions?

28. Do you have class activities that encourage individual students to explain their own thinking to other students?

29. Do you provide adequate time for students to preplan their work off the computer (e.g., think about how to arrange categories and to do searches)?

30. Do you provide adequate time for students to work out their solutions to activities on the computer?

Chapter 10 SPREADSHEETS AS TOOLS FOR THINKING

In the world of business, many decisions are made on the basis of budgets and forecasts built up using spreadsheets. Alternatives are assessed and evaluated, predictions are made, and data is analyzed by spreadsheet users. Use of such a range of thinking skills would seem to ensure a place for spreadsheets in education. However, inside schools, spreadsheets appear to be the least used of the three most common educational computer tools. Our aim here isn't to point out reasons for this, but rather to show ways in which a spreadsheet in the classroom can be a productive and useful tool in development of thinking skills.

In some ways use of a spreadsheet parallels that of a database. A database represents a collection of objects of a particular type, and we manipulate, arrange, sort, and select the data to get at trends, relationships, and communalities. A spreadsheet similarly represents a collection of sorts, except in this case it is a collection of relationships between variables—a system of some sort. Spreadsheet relationships are all numeric with the spreadsheet being able to solve most problems involving numbers and formulae.

There are two stages to working with spreadsheets. Looking at them in the order appropriate for novice users, the first to be considered would be the use of an already existing spreadsheet template. This would be followed by development of spreadsheet templates once students have experience in spreadsheet use.

TEACHING AND LEARNING ACTIVITIES

Using a Spreadsheet Template

In this stage, data is entered into the spreadsheet to see what effect it has on other variables. For example:

- a teacher may have a spreadsheet that enables her to enter student marks for tests throughout the year and automatically calculates class averages for each test as well as maintaining an ongoing average for each student.

- students may use a spreadsheet to compare the return on funds invested at various rates of interest, and work out income when different tax rates are applied to the interest earned.

The real power of spreadsheets lies in the way students can ask "what if" questions. By simply changing an entry in the spreadsheet, it is possible to see the effect of that change on the system as a whole. This "what if" question serves two purposes—it lets students explore the system represented by the spreadsheet, and it also lets them make and test their own hypotheses.

EXPLORE WITH A SPREADSHEET

Exploration serves the purpose of having students identify different ways to solve problems. Students with a budget spreadsheet will discover fairly soon that there are two variables to manipulate to increase their savings—their income and their expenditures. It won't take them much longer to realize that they have three options in terms of action—increase the first, reduce the second, or do both a little bit.

Although spreadsheet applications concerning finance spring to mind most easily, there are numerous other areas in which students are free to explore a system modelled within a spreadsheet. The patterns that exist in problems involving time, distance, and speed could be found. Relationships between sides, diagonals, and angles in two-dimensional figures, or edges, faces, and vertices in three-dimensional shapes can be explored. Climatic conditions—rainfall, humidity, temperature, wind speed, etc.—can be assessed, averaged, and summed, and maximums and minimums can be found. The exploration of population trends is made easier. Survey results can be analyzed.

There is not only a potential for exploring different solutions to problems, but also the possibility of employing different solution strategies. Students can pursue a trial-and-error approach, use patterns to direct a search for solutions, or estimate and move nearer to a solution with each successive estimation. With a spreadsheet, exploring these different strategies can become an accepted part of problem solving.

The way a spreadsheet enables students to manage data easily is one of its important features. One New Zealand teacher has reported how the use of a spreadsheet helped improve his students' decision-making skills. The class was entered in a national business management game—one that involved teams from some of the country's largest companies. The spreadsheet

was introduced as a means of automating most of the many calculations that were involved in the decision-making process. Calculations that had initially taken 30 minutes using pen, paper, and calculators, took only 3 seconds. Where only a few alternatives would have been tried originally, with the spreadsheet many more alternatives could be discussed and taken into account. Decisions were thought through, rather than being made on the basis of a hunch with only a couple of alternatives being closely examined.

That the spreadsheet saves repetitive calculations seems an important conclusion, but the team still had to devise a strategy for itself. It had more time to do this and was able to reach a better consensus after exploring more strategic possibilities. The spreadsheet did the work; the students were required to do all the thinking.

TESTING HYPOTHESES

Use of a spreadsheet to help students plan, predict, and extrapolate from given data is often called the spreadsheet's "what if" capability. Students can change values of (independent) variables and see the effect of these changes on other (dependent) variables; they will be able to see patterns as they develop, confirm predictions, check generalizations, and, as in the example of our school business team, look at likely solutions to problems from various points of view.

A teacher from a local visual resource center, which provides support for blind and low vision students in regular classrooms, had trouble finding a statistics program that was simple enough to accommodate some of his high school students. His solution was to develop a spreadsheet template that produced all the descriptive statistics he wanted whenever students entered the data. As he reports, the students not only get answers to their problems, but also the bonus of "what if" type queries.

> You can do "what if" type queries. With the automatic adjustment set, the student can easily ask questions like:
> a) What happens if I add another two scores? Just move up to an empty data cell and type in two more scores. The entire screen updates instantly!
> b) What happens to the mean if each score is increased by one? The spreadsheet has commands to do this.
> c) What happens to the standard deviation if each score is doubled? Again a simple command achieves the changes. (Offord, 1987)

Using a spreadsheet in this way provides an opportunity for students to extend their understanding of the concepts they are working with.

We have stressed before that the important element is the purposeful use of such a tool, and this is where teachers play a vital role. As students work with spreadsheets, teachers will be encouraging their explorations, challenging their hypotheses, and helping them to evaluate their predictions. Teachers can achieve this by saying things like:

- "Why do you think it is more appropriate to change that entry? Are there any others that you could change to get the same result?"
- "As you change these entries, note which one seems to have the greatest effect on the total. See if you can work out why."
- "Which solution do you think would be more practical in real life? Would you give your reasons to your group?"

Working along with students like this is but one aspect of the teacher's role. As a planner of student learning experiences, the teacher's responsibility is to ensure that spreadsheet examples are ones that students will clearly understand, while at the same time are not so simplistic that a pen and paper exercise would be more appropriate. As Parker (1986) points out, "Real-world examples appropriate to the student's level can emphasize application level thinking and encourage students to make up their own problems for spreadsheet solutions" (p. 23).

Building Spreadsheets

Teachers who are encouraging students to develop spreadsheet templates are starting their students off at the beginning of the problem solving cycle. As students work to identify and then define the system they wish to model on the template, they will have to define the variables involved, check on constant factors, clarify and understand the relationships involved, and in the process, gain a greater conceptual understanding of the area they are working in.

At this level, students will also need computing skills necessary to enable them to put into effect the model that they are building. As a manager of learning, the teacher will have been aware of the need for students to develop such

skills within the experience of using spreadsheets. It is in fact highly likely that students who are initially just using a spreadsheet as a planning aid may wish to investigate some of the relationships behind results they keep getting. Such an opportunity represents the right moment to introduce the topic of spreadsheet formation and the computing skills associated with it.

Along with the chance to investigate relationships behind solutions, students also become aware of the value of problem solving heuristics (e.g., "breaking a problem into sub-problems"). They will then start to use these methods as part of the problem solving process.

Checking that a solution actually makes sense is another example of applying problem solving heuristics. Arad (1985) describes a way of using spreadsheets to solve word problems in mathematics. One of the problems he gives is "Roger has six times as many dimes as nickels and three times as many pennies as nickels. If he has $17, how many coins of each type does Roger have? ' (Arad, 1985, p.13).

The important idea is that students use formulas in setting up a spreadsheet template to solve this problem. Entering values (for the number of coins) enables students to work toward a solution. However, it may have been possible, in this problem, to enter non-integer values for the number of coins. Although an answer would be obtained, it would have little meaning. Students thus need to consider whether use of spreadsheets will always lead to sensible solutions.

The activity of creating a spreadsheet template perhaps shows its greatest value when students work in groups. The importance of social interaction in the development of thinking skills has been discussed earlier. As students work together formulating and contrasting their ideas, they begin to understand their own ways of thinking and are able to learn from others the strategies of checking, predicting, and monitoring their own thoughts.

Skills of analysis and judgement are also called for in the development of a template. Students may develop models that call on them to set factors according to their own values and opinions. For example, they may need to provide a monetary value for the community use of a parkland in order to more accurately decide whether the land is better used for housing or as a park. The need for both group discussion and personal reflection is clear, and teachers will need to allow for both to occur in the class.

A good example of the way a spreadsheet can be used in classrooms is given by Larry Hannah (1986). The spreadsheet was used within a class social studies program to help a group of students rank cities according to their "livability." Spreadsheet activity involved students in exploration, hypothesis forming, and template formation as they worked through various stages of the unit. To begin with, students ranked cities in order of their desirability of living, and the spreadsheet was used to weight the rankings and come up with an overall "best city." This activity sparked much discussion as students compared the criteria they used to rate cities. (See *Quality of Life* tables on the following page.)

In fact, discussion appears to be the key feature of the students' work in this unit. The socially interactive nature of the computer environment comes through often. Hannah mentions how the students discussed the discrepancies that were noted between the student rankings and those of a published almanac, how they discussed the reasons for those discrepancies, and how they discussed which criteria to use for weighting rankings in their own spreadsheet templates. Such discussion involved students in analysis of available alternatives as they sifted through data to decide which factors might be involved. They had to work cooperatively to combine their ideas into the spreadsheet template, and finally, given Hannah's concluding "competition" to "sell" the city they ranked first, each group had to be able to justify the criteria for their ranking.

Examples such as this highlight the way a spreadsheet can be used creatively within the school curriculum to involve students in the sort of thinking that teachers have always worked to achieve in the classroom. As students work with computers in this way, interacting with other students and their teacher, predicting, hypothesizing, exploring, planning, and evaluating, they are developing essential thinking and social skills.

Dallas/Fort Worth

City	Unemploy	Rank	Population	Rank	Pro % Income	Rank	Per cap Income	Rank	Pop Density	Rank	Airport	Rank	TV/Radio	Rank	Winner by Rank
Dallas	5.1	1	904078	2	3.6	1	13846	3	2715	1	2	1	63	1	10
San Jose	7.4	3	629442	3	3.6	1	14998	1	3984	4	0	3	19	6	21
Denver	5.3	2	492365	5	3.2	3	13964	2	4435	5	1	2	42	4	23
Atlanta	7.6	4	425022	6	3.4	2	11590	6	3244	3	1	2	49	3	26
Philadelphia	7.9	5	1688210	1	1.9	5	11946	5	12413	7	1	2	59	2	27
Seattle	9.8	6	493846	4	3	4	13239	4	5879	6	1	2	49	3	29
Sacramento	11.3	7	275741	7	3.2	3	11176	7	2872	2	0	3	29	5	34

Philadelphia

Metro Area	# Of Sport Teams	Rank	Major Museum	Rank	City Park	Rank	Crime Rates	Rank	Major Zoos	Rank	Population	Rank	Hospital	Rank	Total Rank Score
Philadelphia	4	1	4	1	219	2	3785	2	2	1	1,688,210	1	124	1	9
Dallas	3	2	2	2	256	1	9821	7	2	1	904,078	2	42	3	18
Seattle	3	2	1	3	178	4	4986	3	1	2	493,846	4	27	5	23
Atlanta	3	2	1	3	164	6	7896	6	1	2	425,022	6	59	2	27
San Jose	0	7	1	3	200	3	5298	4	1	2	629,442	3	5	7	29
Denver	2	5	2	2	155	7	5362	5	1	2	492,365	5	34	4	30
Sacramento	1	6	1	3	168	5	2979	1	1	2	275,741	7	14	6	30

Students' Spreadsheets for Dallas/Fort Worth & Philadelphia

Figure 2.

Philadelphia

Metro Area	# of Sport Team	Rank	Major Museum	Rank	City Park	Rank	Crime Rates	Rank	Rank *3	Major Zoos	Rank	Population	Rank	Rank *3	Hospital	Rank	Total Rank Score
Sacramento	1	6	1	3	168	5	2979	1	3	1	2	275,741	1	3	14	6	28
Philadelphia	4	1	4	1	219	2	3785	2	6	2	1	1,688,210	7	21	124	1	33
Seattle	3	2	1	3	178	4	4986	3	9	1	2	493,846	4	12	27	5	37
Atlanta	3	2	1	3	164	6	7896	6	18	1	2	425,022	2	6	59	2	39
Denver	2	5	2	2	155	7	5362	5	15	1	2	492,365	3	9	34	4	44
Dallas	3	2	2	2	256	1	9821	7	21	2	1	904,078	6	18	42	3	48
San Jose	0	7	1	3	200	3	5298	4	12	1	2	629,442	5	15	5	7	49

Philadelphia Spreadsheet Modified by the Author

Figure 3.

Hannah, L. (1986). Social Studies, spreadsheets and the quality of life. *The Computing Teacher, 13(4), 13-16.*

ADDITIONAL READINGS IN *THE COMPUTING TEACHER*

Chapter 2—The Teacher's Role

The Learning Center Classroom
by Jeri Hopkins.
The Computing Teacher, 13 (4), 8—12, December/January 1986.
Part of the teacher's managerial role is providing the right classroom environment. This article shows a number of ways of arranging classrooms when computers are part of the class resources.

The Teacher's Role in Using the Computer to Teach Thinking Skills
by Robert M. van Deusen and Jean Donham.
The Computing Teacher, 14 (4), 32-34, December/January 1987.

Chapter 3—Thinking Skills

Developing Higher Order Thinking Skills: The HOTS Program
by Stanley Pogrow.
The Computing Teacher, 15 (1) 11-15, August/September 1987.
Pogrow describes a program designed to teach students "the thinking skills necessary to learn content the first time it is taught in the classroom and be able to apply it to problem solving situations." The part the computer can play in the program is carefully discussed, and the role of the teacher is given explicit attention.

Tools for Thought
by Janet Parker.
The Computing Teacher, 14 (2), 21-23, October 1986.

Productivity Tools for the Classroom
by Shirl S. Schiffman.
The Computing Teacher, 13 (8), 27-31, May 1986.

Chapter 4—Cooperative Learning

Cooperative Learning for
Effective Mainstreaming
by Mary Male.
The Computing Teacher, 14 (1), 35-37, August/September 1986.
Male discusses several cooperative activities designed to increase academic and social skills and shows how these can be related to computer activities.

Chapter 5—LOGO

LOGO, Teacher Intervention, and the Development of Thinking Skills
by Wing Kee Au, Jane Horton and Ken Ryba.
The Computing Teacher 15 (3), 12-16, November 1987.
The importance of effective teacher intervention through careful questioning is stressed in this article about the development of thinking skills. The creation of a Logo environment which is socially interactive and allows for student reflection on the process of problem solving is also described as an essential element of the teacher's role.

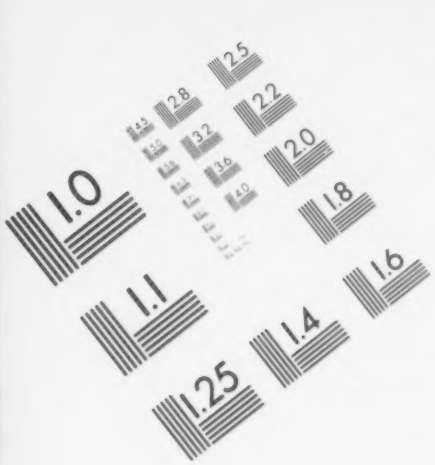
Assessing Learning with Logo: A Pilot Study
by Jane Horton and Ken Ryba.
The Computing Teacher, 14 (1), 24-28, August/September 1986.

Logo Today: Vision and Reality
by Uri Leron.
The Computing Teacher, 12 (5), 26-32, Febreary 1985.

Chapter 7—Word Processing

Computers, Gifted Students and the Development of an Elementary School Newspaper
by Bruce Harris, Melanie K. Arntsen, Richard Thurman and Paul F. Merrill.
The Computing Teacher , 15 (2), 11-13, October 1987.
The authors write about the impact of the production of a school newspaper on the school community, and shows how such a project can prove to be a valuable part of the school language programme.

More Than a Spelling Checker
by Michael J. Kasnic and Sally Stefano.
The Computing Teacher 15, (2), 31-32, October 1987.
A spelling checker can do more than just check your spelling. This article describes some of the ways in which language teachers can use spelling checkers to explore the English language.



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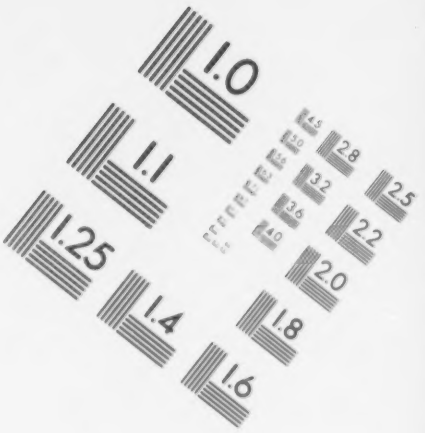

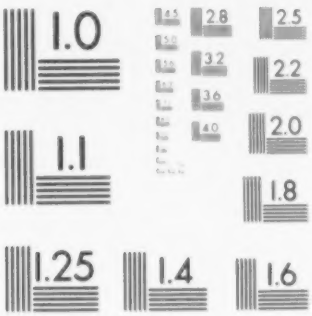

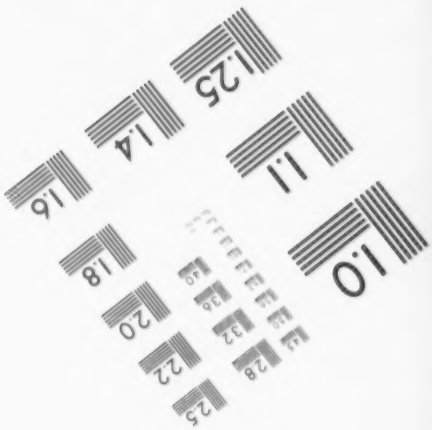

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BY APPLIED IMAGE, INC.

The Computerized Database:
Not a Simple Solution
by Don Rawitsch
The Computing Teacher, 15 (4), 34-37, December/January 1987/88.
Database use in the classroom can be convincingly argued for, but usually on the basis of a variety of unresearched assumptions. Thus argues Rawitsch, who proceeds to investigate several of these assumptions and comes to some interesting conclusions.

The Student-Designed Database
by Rick Thomas
The Computing Teacher, 15 (5), 17-19, February 1988.
Thomas describes a way in which students can collaborate to design a database based on a problem in which they have an interest.

Developing Database Files for Student Use
by Michael Warner.
The Computing Teacher, 15 (7), 44-47, April 1988.
Educational objectives must guide the selection of database content when teachers are building datafiles for student use. A method for creating database files based on this foundation is described by Warner.

Brontosaurus Meets the Computer
by Shirley Krueger, SNJM.
The Computing Teacher, 14 (9), 13-15, June 1987.
Dinosaurs again!. The stress this time is on the use of a datafile of the ancient reptiles and the illustration of a number of ways in which students' higher level thinking abilities can be developed within database use.

Teaching Database Search Strategies
by Larry Hannah.
The Computing Teacher, 14 (9), 16-22, June 1987.
Driving a database is a collection of skills which must be taught. The activities presented in this article are designed to help student become familiar with efficient ways to carry out database searches.

Problem Solving with Databases
by Beverly Hunter.
The Computing Teacher, 12 (8), 20-27, May 1985.

Chapter 10—Spreadsheets

Beyond Distance = Rate * Time
by Marty Karlin.
The Computing Teacher, 15 (5), 20-23, February 1988.
Dinosaur's are a favourite topic with children everywhere. This article about a dinosaur based project shows how a spreadsheet can be used to help students understand some of the processes of science.

Spreadsheets in the Classroom Parts I & II
by Joan Marie Brown.
The Computing Teacher, 14 (4-5), December/January & February 1987.
This two part article is a series of four lesson plans providing activities for introducing the spreadsheet to a class.

Spreadsheets: More Than Just Finance
by Art Luehrmann
The Computing Teacher, 13 (7), 24-28, April 1986.
The difficulties involved in introducing spreadsheets to a classroom are explored in this article. A sequence of concepts to be taught is suggested and the need for interesting examples is stressed.

Social Studies, Spreadsheets and the Quality of Life
by Larry Hannah
The Computing Teacher, 13 (4), 13-17, December/January 1986.

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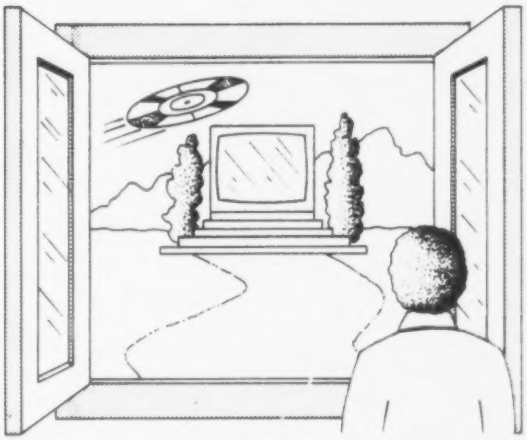

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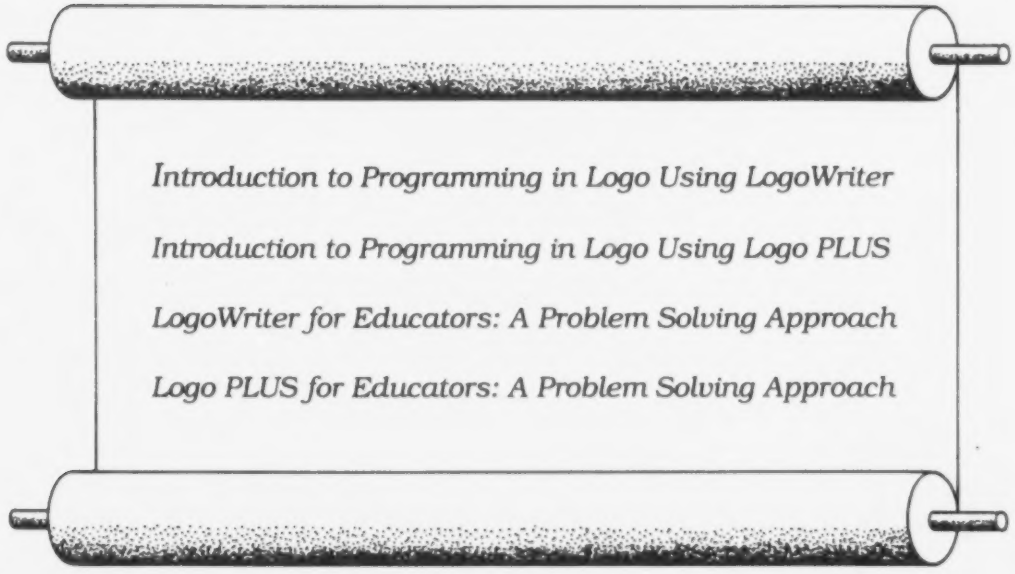

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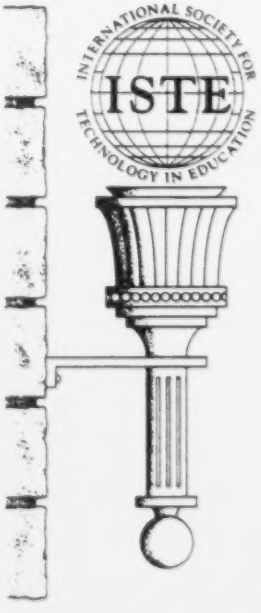

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